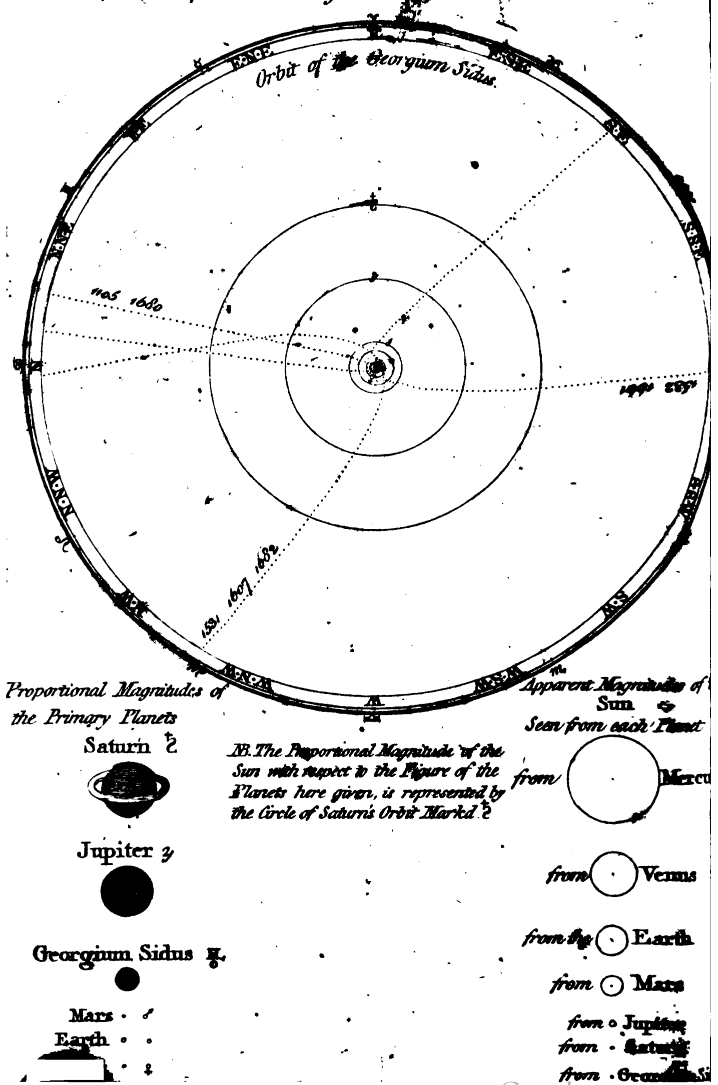
THE

SYSTEM OF THE WORLD.

View of the Proportional Magnitudes of the PLANETARY ORBITS



THE SYSTEM OF THE WORLD.

BY

M. LAMBERT.

TRANSLATED FROM THE FRENCH,

By JAMES JACQUE, Esq.

Omnia in mensura et numero et pondere disposuisti.
SAP. I. xi. v. 21.

LONDON:

PRINTED FOR VERNOR AND HOOD, 31, POULTRY;
AND J. CUTHELL, MIDDLE-ROW,
HOLBORN;

By J. Cundee, Ivy-Lane.

1800.

PREFACE.

LETTERS on Cosmogony, by Mr. Lambert, were but little known in France, except from an extract inserted in the Encyclopedian Journal for the year 1765, when I formed the design of giving them a greater degree of publicity. I might either have translated or digested them; but I preferred the latter method for good reasons.

These Letters have somewhat of the freedom of arrangement which the epistolary style admits: the different subjects are blended together, and the train of ideas break off abruptly; circumstances which require frequent references to what has gone before, and a degree of attention not easily commanded by the bulk of readers. But, with the extract abovementioned before me, I have been enabled to save them that trouble; in it each subject has found its proper place; and, as the whole is exhibited in a luminous point of view, I had only to pursue the same order, and to work on a canvas already traced to my hand. I thought these advantages might compensate the reader for

the

the loss he would sustain in respect of the beauties of style, which, besides, a translator but rarely succeeds in transfusing from one language into another.

It has been my chief study to comprehend fully the ideas of my author, and to deliver them clearly and with precision. As I had it not in my power to consult himself, I submitted my labours to the revision of a philosopher and mathematician of the first eminence, who honours me with his friendship, and whose name would suffice to impress the public with sentiments favourable to my work.

I would have wished to execute this undertaking in a popular manner suited to the weakest apprehension, had it been possible, without making sacrifices of too much importance, to extricate the subject entirely from the technical peculiarities of geometry and astronomy. Provided, however, the reader possesses but a smattering of those sciences, he will not find it difficult to understand the subject; even without it he may easily form an idea of the system here proposed.

CONTENTS.

PART

CONTENTS.

PART II.—CHAP. I.

ENCOMIUM

ENCOMIUM

OF

MR. LAMBERT.

In entering upon the task which I ought this day to perform; a task painful, and, I am afraid, greatly above my abilities; methinks I see a Janus with two faces, equally extraordinary and difficult of delineation. One offers to the eye, a sage, and in him a bright assemblage of all the features, of all the knowledge, of all the talents, which contribute not only to immortallize the man of letters and the philosopher, but which, shared among several individuals, would be sufficient to entitle them to celebrity. The other presents a man; a man, simple and unaffected, such as nature forms him when unassisted by art. He reminds us of that block of marble which puzzled the statuary whether he should convert it into a god or a bason. Such men are certainly rare; perhaps it is impossible to describe them better than by a sort of characteristical detail. The particulars which have been obligingly communicated to me added to what we ourselves have all seen and remarked, will probably distinguish this *Elogy* from the bulk of others, where the author had to represent common objects only from vague and general materials.

John Henry Lambert was born at Malhausen, on the 28th of April, 1728. All that can be said of the first years of the life and education of literary men, amounts to little more than a sort of common-place insipid detail. From school they were sent to college; they were endowed with excellent dispositions, they were placed in a situation to cultivate them with success, and hence they acquired high attainments in the pursuits of learning, and rose to the employments they actually hold; in all this we often meet with nothing but obscure names and useless dates. On the present occasion, there is not an incident which we ought to lose, nor a single circumstance that ought to be omitted.

The

The father of our academician was an honest citizen, a stay-maker, whose grand-father having emigrated from France on account of his religion, retired to Mulhausen, where he obtained the freedom of the town. As opulence but seldom accompanies the refugee, that family remained in very straitened circumstances; and Lucas Lambert, the father of John Henry, found it very difficult to live by his vocation. The education of the son was adapted to the nature of his father's business, to which he was destined. They turned his views into this channel, and applied his talents to stay-making, without dreaming, or being able to foresee, that he should ever emerge from so narrow a sphere, to ascend even to the confines of that of the universe. The family of Lucas having multiplied, the occupations of young Lambert, who was one of the eldest, became daily more numerous, and, if I may say so, more irksome and humiliating. He was obliged to render his brothers and sisters all those offices of which their age and wants stood in need. Or, in plain language, he performed alternately the duties of an apprentice and a servant.

 His

His education, however, was not entirely neglected To the age of 12 years his father sent him to the public schools of Malhausen, where he soon distinguished himself by the assiduity of his application, leaving all his companions behind him, and giving early and unequivocal proofs of his ardent desire of knowledge; a circumstance, however, which was far from suggesting to his parents the notion of encouraging him to persevere in his studies. On the contrary, young Lambert was bound in due form to his father's profession, and was obliged to exchange the pen for the needle.

The youth, who in every period of his life was of a decided character, and incapable of bending to the will of others, declared respectfully, indeed, but with firmness, that it was impossible for him to embrace such a manner of life, which he regarded, besides, as incompatible with his constitution, then but delicate. He neither could nor would rebelliously withdraw from it; but he redoubled his importunities, and, in the mean time, suffered no means to escape him of learning something. While he rocked the cradle with his

foot

foot in a very noisy habitation, he held a book in his hand which he read with the closest attention.

Here I am to mention an anecdote, which shews still farther the almost invincible difficulties he had to contend with, as well as the magnanimous courage he was prepared to oppose to them. His mother, in order to prevent his reading when he ought to be asleep, denied him the use of a light. Young Lambert had been at much pains in learning to write a fine hand, which was afterwards of great use to him: he wrote and drew extremely well; he made little designs or drawings, which he sold to his companions for a farthing or a halfpenny according as they contained more or fewer figures; and from this money he supplied himself with candles, which he lighted the moment all those of the family were put out. Providence employed his lucrubations as the means of preserving the lives probably of the whole family. One evening somebody had the indiscretion to throw hot ashes into a garret, which, kindling fuel that happened to be mixed with them, a plank caught fire immediately over the student's chamber; he perceived it, and alarmed his relations, who had still time enough to extinguish the flames, the violence of which must soon have involved them in ruin.

It was no longer possible to resist his unwearied perseverance. Besides his masters bore frequent testimony to the boy's extraordinary capacity, and made his father sensible of all its importance. He at length yielded, and, addressing himself to the masters, beseeched them to lend every assistance in their power to their pupil, and to help him through those difficulties which lay in his way to that career on which he was so desirous to enter. It is proper to observe, that at this time the number of men of letters at Malhausen was confined to half a dozen of divines: for it was an article of the popular belief, that there is no real science but theology, nor any other set of men fit to cultivate the sciences but theologians; and hence they drew this natural conclusion, that they ought to give their countenance and encouragement to none but to those who devoted themselves to this sublime study. As there was no option, Lambert, the father, applied for a bursary or pension to enable his son

son to prosecute his theological studies; but he met with a refusal; and the most earnest and reiterated solicitations could make no impression on the dispensers of these charitable donations.

We may easily imagine the grief, or rather despair, of young Lambert, when he found that the only hope he could rationally entertain of continuing his studies had totally vanished. His parents resumed all their former severity, and declared to him, that however much they might pity him, yet it was plain he must labour, and trust to his own fingers for the means of his subsistence. Lambert sighed, but submitted, returning to his former condition of journeyman taylor and servant. Even this double yoke became still more grievous, and he would probably have sunk under the burden, had not one of his brothers, who at this day exercises the same employment, came to his assistance by frequently finishing the task he had begun, but had not strength enough to accomplish.

In the midst of these domestic occupations, one of his companions lent him a book on

Arithmetic and Geometry. He no sooner opened it than he found himself in a region suited to his taste, and which he had the most eager desire to explore. Such is, in general the first annunciation of original genius, which contains a bud concealed from itself, and which owes to some lucky accident its first disclosure. It was thus that la Fontaine, to whom Mr. Lambert has often been compared, seemed to awake from a lethargy in which he had hitherto been immersed, upon hearing emphatically read to him that ode of Malherbs :

Que direz vous races futures,
Si quequefois un vrais discours,
Vous recite les avuntures,
De nos abominables jours.

One would be curious to know what was the first book by which young Lambert begun. All we know is that he studied it with infinite assiduity, and made himself master of it from beginning to end ; but what affords a still more striking proof of the energy of his genius, he discovered several errors or mistakes in it without being able to correct them.

But

But we have not yet done with those auspicious symptoms of latent genius. The house of Lambert the father having gone to decay, the tradesmen were employed to repair it. The young man, contemplating their operations with the book in his hand, asked them various questions respecting the practical application of those principles, in which he had been initiated by his own talents; and he discovered such a perfect knowledge of his own questions, which were the more surprising as they came from the mouth of a plain journeyman taylor, that one of the principal workmen conceived a friendship for him, and promised him a book of the same kind with his own, but more extensive and full of plates. The young man was transported with joy, in prospect of so rich an acquisition; he followed the tradesman home, and made him give him the book without a moment's delay; he perused it with a greedy appetite; but what doubly charmed Lambert, it happened, by some strange accident that this was a work precisely intended to correct the errors of the one he had read. It was now that to the feeble ray which had hitherto guided him in his studies, succeeded a light which continued through life to acquire

addi-

additional strength. He learned arithmetic and geometry without a master or assistance of any kind except what he derived from these two books. He has declared oftener than once, and on no occasion has his veracity been suspected, that in spite of the dryness of these two sciences, he was never disgusted even for a moment, nor found himself stopped by the difficulty of the subject.

Such a phenomenon, had it made its appearance in the bottom of Beotia, would have produced a sensation. Even at Malhausen it found men of estimable characters though not theologians, who not only advised and encouraged Lambert, but gave him private and gratuitous instruction, for which they deemed themselves amply rewarded by the astonishing progress of their pupil.

In this manner, and still in the bosom of his native country, he laid the foundation of his knowledge in philosophy, and even applied to the study of the oriental languages. He perfected himself at the same time in his hand writing, which he prophesied would be the first means of gaining his bread. The

truth.

truth is, it obtained him the advantage of being employed as a copyist in Chancery, over which Mr. Reber presided. At the age of fifteen he became impatient to learn the French language; but his parents not being in circumstances to afford the expence of a master, he engaged himself, as a clerk or book-keeper, to M. de la Lance de Montbeliard, who was concerned in the mines of Sepoix in Upper Alsace. At the end of two years, as he thought himself sufficiently instructed in French, he was anxious to live in a situation where he might indulge his whole passion for study. He had the good fortune to obtain the place of Secretary to Mr. Iselin, Counsellor of the Margrave of Bade-dourlach, and resident at Basle *; where he then published the Political Gazette. Mr. Iselin conceived a strong affection for Lambert, which he retained ever after, and of which he never ceased to give him the most convincing proofs. Nothing could more fully express the generosity of his friendship,

* He was likewise Professor of Law, and had some reputation among the Lawyers at Basle. He was an Assotiate of the ancient Royal Society of Sciences at Berlin, and continued to enjoy the same character in the academy. He died in the year 1779.

than

than that Mr. Iseling, notwithstanding the desire he had to keep him attached to his person, chose to deprive himself of that advantage by procuring him an employment whence we may date the whole happiness of our illustrious sage. It was that of tutor to the grandsons of M. le Comte de Salis at Coire. He entered upon the functions of his office the 17th of June, 1748, and lived in the family eight years.

But that we may have a distinct idea of the family to which Mr. Lambert was attached during the above period, it is proper to observe, that it was that of M. Pierre Salis Comte of the Holy Empire, formerly Envoy Extraordinary at the court of London, and who had been one of the Negociators at the peace of Utretcht. This gentleman had then attained to fourscore years, and united in his character all the eminent virtues of the statesman, the patriot, and the christian philosopher. His wife, an English lady of the best character, was still alive.

The pupils of Mr. Lambert were the grandsons of the Count, and sons of the Podestate of of Coire. It was now in instructing his charge, that Mr. Lambert found all those means of instructing himself of which he had hitherto been so much in want. Becoming more and more conscious of the strength of his natural powers, he embraced, without hesitation, physics, astronomy, mathematics, mechanics, nor did he deem himself unequal to the studies of theology, metaphisics, eloquence, and poetry. He composed verses in all the languages he understood, German, French, Latin, Italian; but he would not dare to attempt the versification of the Greeks. If the Muses did not honor him with a place among their firs tfavourites, he derived a more solid satisfaction from the pious strain of his hymns. I am of opinion, however, it is my province to insist more upon the fruits of his learned labours than upon his poetical eccentricities.

Let us now return to the proper object of his pursuit. Having one day read that Paschal invented a certain arithmetical machine, by a mere effort of his own genius, he could take no rest till he invented one of the same description. He likewise constructed with his own hand a mercurial watch or pendulum, which

which kept going 27 minutes, and served to ascertain precise portions of time in his physical experiments.

His arithmetical scales, and a machine for facilitating the art of drawing in perspective, are no less worthy of our notice. A singular accident, for accident itself seemed to submit to rule in favour of Mr. Lambert, led him to this last invention. He had proposed, as an exercise, the solution of an algebraic problem to one of his pupils; the young gentleman, in the course of the operation, committed a mistake of calculation, and, finding himself unable to rectify it, abandoned the task to his master. Mr. Lambert laboured in the investigation of the error for several days without success; at last, after spending much time in profound meditation, he cried out, like another Archimedes, "*I have found the error, and that error to me is worth a discovery:*" he executed the same day his machine for perspective drawing. His notions of aggregates, from which he afterwards composed his *Algebraic Logic* and his *Novum Organum*, we, in like manner owe to his lucubrations of the same period.

The rapidity of his progress, and the extensive knowledge he had already acquired, induced him to become a member of a literary society, which some persons of distinction had instituted at Coire, and which served to introduce him to the particular acquaintance of Mr. Professor Martin Planta, a man distinguished by his talents, and, above all, by a rare genius for the mathematical sciences; to whom, among other obligations, the public is indebted for superintending the arrangements introduced into the seminary which was founded at Haldenstein.

In 1753, there occurred a certain dispute between the town of Coire, the capital of the country of the Grisons, and its Bishop. Mr. Lambert framed memorials on the part of the town, which did him honor. The same year he became a member of the Helvetic Society at Basle, to which he presented several mathematical and physical dissertations inserted in the *Acta Helvetica*.

In this manner, eight years passed away, perhaps the most fortunate in the life of Mr. Lambert, but which announced others still

more

more glorious, the premature termination of which we have this day to deplore. On the first of September, 1756, he quitted the house of de Salis, with the third son of the Podestate and one of the nephews, to spend a year at the university of Gottengen, and then to travel. When at Gottengen he made a tour to Hartz, and visited the famous mines of those mountains. Before he left the university he was named a Corresponding Member of the Royal Society of Sciences.

From thence the tutor and his pupils repaired to Utretcht, and passed a year in Holland; where Mr. Lambert gave to a bookseller of the Hague his treatise on the Passage of Light. But in the over ardent pursuit of this object, he found himself in the situation of the astrologer, who fell into a well; this deplorable accident brought him to the verge of destruction, and shook his constitution in such a degree that I suspect he felt the infirmities it brought upon him to the last day of his life. In consequence of a habit equally whimsical and invariable in him, he never presented himself but sideways, changed his position as often as the person with him sought to place himself in front, and he retreated in proportion as the other advanced. It was in a situation of this kind, that, making some steps backwards without attending to a stair case which was directly behind him, he fell at once from top to bottom, heels over head. The fall was dreadful; he lay long in a state of absolute insensibility, nor did he return to his senses till the end of twenty-four hours, when he opened his eyes totally black with extravasated blood; his physician never could make him give credit to the duration of his asphixy or faint. I cannot say whether in this respect he resembled the celebrated Bossuet, who, after a faint of some hours, said to those who attended him; "*how is it possible that a man like me should exist so long without thinking?*" Be that as it may, Mr. Lambert's recovery required a very considerable time, and all the care of the same physician, Mr. Halm, a celebrated professor at Utrecht, who advised him to abstain from close study for the space of two years; but of all possible reigmens, he could mention none, with which Mr. Lambert could less bring himself to comply.

At Leyden he had a very pleasant adventure with Mussembrock; it must have been of the most risible description. The professor, whose locks were become white in the exercise of his office, upon receiving the visit of Mr. Lambert, took it as the homage of a schollar to his master. Accordingly Mussembrock began to chatechise him, and to pursue a sort of detail which Lambert's knowledge left far behind. He replied to the learned professor with those firm tones, and that extreme volubility, which he had so much at command; and, having soon gained ground on the good man, the dialogists changed characters; Lambert was the master, Mussembrock the schollar.

Our travellers arrived in France. During his stay at Paris, Mr. Lambert saw the principal geometers, astronomers, and natural philosophers of the country.

He was introduced to D'Alembert, who saw and felt his extraordinary merit; and he received, above all, many marks of friendship from M. Messier, famous for his astronomical observations and discoveries.

From

From Paris they returned to the country of the Grisons by Marseilles, the county of Niece, Piedmont, and the Milanese. Mr. Lambert knew well how to employ his travels for the extension of his general knowledge, as well as for his improvement in particular objects.

Upon his return to Coire, he passed some time in the house of M. de Salis, which he, at length, quitted in the month of May, 1759, on a visit to his native soil. As he passed through Zurich, he gave his *Perspective* to the press. Arrived at Mulhausen, he found his mother still alive; (his father had died in 1747) he lived three months with his mother, and parted with her for ever, for he lost her in the course of the same year.

In the month of Sept. 1759, Mr. Lambert was at Ausburg, where he spent some time, for the purpose of giving the last touch to his *Photometry*, and to have it printed under his own eye. At the same period was instituted the Electoral Academy of Sciences at Munich, which chose him one of its members; they likewise expressed their desire to have him more particularly attached to them by engaging him to furnish them literary papers, and to assist them with his advice. As a remuneration of his services, he received the title of Honorary Professor, and a pension of 800 florins. He reserved to himself the privilege of living any where he should think proper without the limits of Bavaria. This connection, however, was of short duration. They accused him of not having the interest of the learned academy sufficiently at heart; and he complained in his turn, and probably with more reason, that they neglected his advice, and were at no pains to reform the abuses which he pointed out to them. They withdrew his pension, and he would not condescend to take any step for its recovery.

Mr. Lambert was too much occupied with the abstract principles of science to give his thoughts to things so material; and, yet he was by no means in easy circumstances. He was satisfied if the profit of his works would enable him to lead the life of a philosopher from one publication to another; just as Scarron formerly lived on the revenue of his Marquisate of Quinet; it was thus he used to term the price he got from his bookseller Quinet,

for

for his burlesque productions. Those of Mr. Lambert would have had no price were the tariff of the trade regulated by intrinsic value; or, if the sale of the commodity were accommodated to such a standard; but, we all know, that trifles take wing, while works of solid merit remain at the bottom of the repository. The works of Mr. Lambert, however, have been duly appreciated by competent judges, who, by bestowing on them a distinguished reputation, have unalterably fixed the high rank the author has since held in the republic of letters. In the year 1760, he collected the different pieces, still in a fugitive state, of his *Novum Organum*; but which was not published till the year 1764. In the year 1761, he published his Treatise on the Properties of the Orbits of Comets, printed at Ausburg. The torrent of his ideas, which flowed incessantly and rapidly from his brain, ever brought along with it useful materials for the construction of the system of the world. In these consisted his wealth; and no man could say, with more truth than himself, that all he was worth he carried about with him.

I neither am able, nor, indeed, do I wish to give an accurate and chronological list of Mr. Lambert's works, still less to analize them. Two of my illustrious colleagues have given an opinion on this point; and, from them, nobody, I believe, will chuse to appeal. The reputation of his works is established, and posterity will confirm the decision of the present age. But what I am desirous to bring particularly under the view of this respectable assembly, is a thing singular of its kind: I mean the history of Mr. Lambert's intellect during the space of 25 years, the progress of his genius, his rapid advancement in knowledge, and the series of his operations, which he noted with equal truth and simplicity, in a sort of journal which is continued from the month of January, 1752, to the month of May, 1777. Such are those fugitive leaves more precious than the leaves of the Sybil. Never were there any which better merited to be preserved; and I request of the academy that they may be printed and annexed to my *Eloge*, on which they will bestow life and value.

Berlin

Berlin had long attracted Mr. Lambert by many ties; above all, he had a most valuable friend, Mr. Sulzer, who, for many years, had courted his visit; and who, at length, had the felicity to grasp him in his arms in the month of February, 1764. Here commences a new epoch, upon which I shall insist the less, that I address myself to those who are equally informed with me as to what it has produced; but, it is necessary to enter into some detail for the instruction of those who are to come after us.

Mr. Lambert was a man with whom the eye and the ear found it extremely difficult to become familiar. Mean and singular in his dress, he presented himself in a very awkward manner; a stranger to the received usages of society, or careless of conforming to them, he seemed to be occupied with nothing but himself; his philosophic volubility of tongue was unceasing till be found himself alone; and, even then I have seen him, after broaching a subject with some person who was called away, go on and finish it as if he had been speaking all the while to an attentive hearer. Add to this, that flashes of self-love, and expressions of the high idea he entertained of his own merit occurred so often, that the conclusion seemed to many to be at war with the premises. One might observe, however, if he were at pains to examine him, that if he spoke frequently in this offensive manner of himself, he was actuated neither by pride nor ostentation. These passions have more subtilty and address; nor do they pursue the attainment of their end by means so gross and palpable. Mr. Lambert spoke from a pure and simple intuition of his own worth; from an intimate acquaintance with his excellent endowments, and their intrinsic value; and, above all, from an ihtire satisfaction in the manner by which he had acquired his eminent riches, namely, by himself, by the force of his own genius, and, by his assiduous application to study: Meanwhile giving himself no manner of uneasiness as to what others might think of him, nor caring either to please or displease, he was uniformly without disguise; and, as he shewed himself on all occasions in the same colours, he at last subdued the prejudice, and forced the admiration of others to identify itself with his own.

We have ever been sensible of the inconveniencies attached to his manner of acting and conversing; but we found his weaknesses compensated by so many inestimable qualities of the head and heart, that we came finally to regard him (I call you, gentlemen, to witness) as an ingot of pure gold, whose value could not be enhanced by the fashion of the artist.

The King called him to Potzdam in the month of March. It was a moment not a little critical in the fortunes of Mr. Lambert; and, at first, his stars seemed to decide against him. The peremptory tone of his answers; the confidence with which he replied without hesitation to the quesstion—*Que savez vous* *? —*Tout, Sire,*—and then *Comment l'avez vous apris?*—*De moimême.* †—Striking ears, but little accustomed to such sounds, might naturally enough excite a suspicion, that the repletion of his brain had discomposed some of its main springs. Here the interview ended, but without effect; nor did it seem to leave the smallest chance in his favour; but the great

* What do you know?—Every thing.

† By what means have you learnt it?—By myself.

Frederick

Frederick, let into the singularity of the man, who, as one of our worthy colleagues daily honoured with his Majesty's conversation, assured him, bore a strong resemblance to the character of La Fontaine, would not deprive his Academy of a member from whom so much was to be expected. He was therefore admitted with a pension, and pronounced his inaugural oration in the month of January, 1765. Since that period, his Majesty honoured him with frequent and distinguished marks of his esteem; placed him in the financial commission of the Academy, and the architectural department, with the title of Superior Counsellor, at the same time making a considerable addition to his appointment. During these twelve years, which have passed away like a dream, Mr. Lambert, in his proper element, devoted his incessant labours to the improvement of science and the public good. He published some excellent performances, and furnished tracks without number, which have been inserted in the *Memoires* of the Academy, the Astronomical Tables of Berlin, and other collections. All his writings are highly expressive of a universal and original genius.

He

He possessed great powers of invention; and the facility with which he availed himself of those resources might probably be derived from his first wants. Not possessing himself, and being in no condition to obtain the instruments necessary for making observations, or a single machine for the purposes of experimental philosophy, he contrived to supply that deficiency by making them of the most common materials that fell in his way; and the dexterity he came to employ in the management of them made amends for the imperfection of their construction. It is difficult to imagine the extent of his acquired skill in the use of such means; but I must not dissemble that I think he would have been still more successful in his main object, if, when he came to have every thing of that kind which he could desire at his disposal, he had not, whether from the effect of habit, or a certain degree of constitutional obstinacy, persisted in constructing his own apparatus; a circumstance, I am persuaded, which prevented his attaining that nicety and precision for which his mind was so excellently formed.

I will attempt, with your permission, to analize Mr. Lambert's character, in order to its being more completely understood. It has never been my custom to mix satire with praise, nor have I ever wished to overcharge the language of eulogium; but I have always thought that this species of composition, like the art of painting, admits of certain degrees of shade for the purpose of giving brilliancy and effect to the luminous masses.

The science of Geometry embraced nothing which Mr. Lambert did not know; nor has he done any thing in this branch of learning that is not highly estimable; though perhaps he has not arrived either at the depth of views, or dexterity of calculation which characterize three or four of the first mathematicians of the age. He excelled in all the departments of mechanics, was constantly sifting and labouring some interesting point on this subject, and he certainly carried the science of mechanics farther than any philosopher that had gone before him. His attainments in Astronomy and Cosmogony were sublime; and by a kind of affinity between Mr. Lambert and light, he was enabled to pursue it in all its mazes, and to analize it in all its properties in a manner to

invite

invite the attention of the great Newton, could we suppose him to have any knowledge of the labours of a rival not unworthy to break a lance with himself. "The comet which Mr. Lambert "had observed in his early years," to borrow a remark from Mr. Bernoulli, I make use of his own words, "seem to have had a decided in-"fluence on the nature of his future labours; it "was the primary cause of his ingenious work "*Insigniores Orbitæ Cometarum Proprietatis*, "and of several excellent dissertations on com-"ets in his famous *Beyträge zur Angewandten* "*Matematik*, and others; as well as of bringing "to light his singular talent for geometrical con-"structions." In general whatever is susceptible of mensuration Mr. Lambert wished to determine; and perhaps there are no measurements capable of being ascertained that he has not either taken or attempted to take. Besides the evidence of this which is contained in his works, I find in the list of his avocations, a *Pithometry*, or the Art of Gauging, to which he gave much application; and a *Pyrometry* which by the last line of his Journal appears to have been finished on the 16th of May last year.

Logic

Logic and Ontology gave exercise to the activity of his mind; two of his greatest works the *Organon* and the *Architectonique* are respectable monuments of his sufficiency in those subjects; but it appears to me that the public content themselves by paying them a certain tribute of respect. They looked for the discovery of new paths in those thorny regions; I shall not pretend to decide whether Mr. Lambert actually found them: I attend only to those who have followed him on the same ground, and whether it be that travellers chuse to keep on the patent road, or that they have not been sufficiently convinced that any thing is to be gained by quitting it, his route is almost entirely unfrequented.

Mr. Lambert was a stranger to the three kingdoms of nature*: he had never given his attention to individuals, nor to facts in that arrangement. All his points of view centered in the starry vault, in a straight line before him, and in the chamber of his brain, where he was continually immured, even when you thought

* He was however tolerably conversant in chemistry; he made vairous experiments on salts; which made the subject of different papers read in the academy.

you

you were with him, and fixed, or at least divided his attention. No divergency in him either to the right or to the left, always in the region of abstractions, objects in the order, of what are called concretes scarcity grazed his sphere.

In fine, it must be admitted that he was almost destitute of taste; nor was this owing to his neglect of those smiling fields where this fair flower shoots and flourishes; we have already seen that he ventured to climb Parnassus; but in spite of his partiality for the muses, he was ever ready to ask as to subjects of taste, *What does it prove?* I should not have chosen to speak so plainly on this topic in his life-time; I was no stranger to his pretensions to wit: I got a sight of a *memoire* in form of a dialogue, which he had been at pains to besprinkle with attic salt; but in which the academician in disguise had too strong a resemblance to a player out of his part. Great men would drive their inferiors to despair, if they paid no tribute to humanity.

I have now only to delineate him in his moral aspect; but it well merits our contemplation;

plation; and I should be glad were it practicable to represent it by a single stroke. Mr. Lambert was upright in every sense of the word. Rectitude of views, rectitude of intentions, rectitude of action. I will not be accused of attributing to him impeccability, more than infallibility. But if we could say of men as Horace says of authors:

——Vitiis nemo sine nascitur; optimus ille est,
Qui minimis urgetur *,

that *Optimism* was unquestionably a proper attribute of the deceased.

Fontenelle, as he concludes his *Eloge* of Ozanam, informs us, that it used to be a saying of this academician, *that it is the prerogative of the mathematician to go to Paradise in a perpendicular line.* This, I have no doubt, was Mr. Lambert's route upon quitting the earth; nor had he occasion for a chariot of fire to carry him to heaven, a single ray of light would afford him a vehicle. In proportion as his intellectual pursuits were various

* No man is born without faults; the best is he who is subject to the smallest.

and

and complex, and that they were so I have already shewn, the plan of his life was simple and uniform. Each day of his existence began, went on, and ended in the same manner. He was by no means an enemy to society, nor insensible to some of its pleasures. Occasions have occurred when perhaps he might have followed more strictly the rules of self-denial. But he violated them no otherwise, than he violated the rules of modesty, when he spoke openly and without disguise of his own superior talents and learning. Whether he eat, drank, or spoke, he went on his own way; he knew not what it is to stop or turn aside: a peculiarity however which never betrayed him into excess, properly so called.

From the perfect rectitude of his mind, arose that constancy or firmness which he carried at times the length of obstinacy. It was necessary so to speak, to get out of his way; otherwise he would jostle and overturn without concern, distinction or exception of persons I will not say that his early education might not bring him on to an age too far advanced for acquiring those pliant manners, and that facility of deportment, which we see in many instances, degenerate into grimace and bodily contortions. Until late in life he had no access to what is called the great or fine world; but feeling in himself more real beauty and grandeur than he found in those whom he met usually in fashionable circles, he assigned a place to himself, from which it would not have been an easy matter to dislodge him. Such is the effect of the most precious of prerogatives *mens conscia recti* *.

We will conclude this part of Mr. Lambert's Eulogium by again observing, that he had religion, and even devotion, that he was still more a christian than a philosopher, and that all the erroneous flights of a certain false philosophy were utterly unknown to him. He was too great a man to condescend to its acquaintance. His journal takes notice in the month of January 1755, of a composition intituled *Oratio de characteribus Christiani, ejusque præstantia Præ Philosopho.* His whole life has been a commentary on this text, and an incontestible proof of it.

Such is the man we have lost; his years did not extend to half a century; we shall see him

* A mind conscious of its own rectitude.

no

no more. I recollect the exclamation of Flêshier in his funeral oration on Marishal Turenne. The orator, as he announced the death of that hero, cried out, *powers, enemies of France, ye live!* I say, but on a more solid foundation, Lambert is dead, and ye live ignorant mortals; ye live enemies of knowledge; ye live an useless burden on the earth, born to consume its good things without the capacity to produce one. When I turn my eyes to the place where we were accustomed to see our illustrious colleague, and where we saw him with so much pleasure, and where we used to hear him speak as if he had been inspired, I say to myself, certainly without the smallest intention to detract from the merit of any man: that place, is it filled? or, rather, shall it ever be filled again?

I draw back, and, in some sort, would be glad to avoid the recital of the catastrophe; but we must come to it; we must approach that grave where lies the mortal coil * of an immortal man.—The constitution of Mr. Lambert had been of a weakly habit in the first years of his life; the accident of which we

* See Shakespeare in Hamlet.

have spoken gave it a violent shock, if it did not occasion, inwardly, some irreparable mischief; nor was he, by any means, sufficiently attentive to such precautions as, by sparing the bodily organs, might have continued their duration a long time; but, after all, his frame was far from announcing a sudden decline, much less an end so rapidly approaching. We saw him, for some years, with a florid complexion and in good plight; though this was to be regarded rather as the sign of actual health, than of vigour and a durable system. It required the force of a regularly formed disease to unhinge him, and that he should undertake his own cure to lay him in the dust. His disorder was a violent cold, caught in the winter of 1775. He suffered it to take its own course, without minding the application of those simple medicines which soon restore a constitution still active, and, in circumstances, to assist itself. The disease was of long continuance, but its progress was nevertheless visible; he was the only person himself who was insensible of his danger; he declined medical assistance till it was too late; and, even then, he received it in a careless manner, chusing rather to be guided by his own whimsical regulations.

regulations. His person melted away like wax before the fire, till, at length, all that remained of him, was a parched and yellow skin glued to the bone. In this state, and with symptoms by no means equivocal of his approaching dissolution, he asked his physician, seemingly by way of curiosity, whether, in such a plight, a man might not last a long time, fifteen years, for example? I saw him in the Park, at his dish of coffee, on the 18th of August, when we had some conversation: he talked of the state of his health like one who was completely master of his disorder, who was not afraid of it, and knew well how to get rid of it. *I have disembarrassed myself, said he, of five or six hundred catarrhs;* I use his own words; *they are now nearly gone*: He was not mistaken; the source of vital moisture was dried up. He continued, however, to walk about, though scarcely able to support himself; but still his head seemed to have no sympathy with his bodily weakness. We saw him in this assembly on the 18th September, more dead than alive; he had even a convulsive symptom which alarmed those who observed it. On Monday the 22d he wrote me, with a paper of Mr. Segner to be presented, as he foresaw

 he

he should be too weak to attend the next meeting. The day of that meeting, the 25th of September, was, indeed, the day of his death, though unforeseen by himself. He entertained himself as usual with the objects that occupied his thoughts, much in the same manner as Leibnitz, a few moments before he expired; and amused himself with the process by which Furtembach converted the half of a nail into gold; he took a light supper much in his ordinary way, and with his ordinary appetite! after which a slight stroke of apoplexy sent him from this mortal to an immortal society, where no man ever carried with him a better title for admission, nor a better state of mind for enjoying and improving in it.

INTRO-

THE

SYSTEM OF THE WORLD.

INTRODUCTION.

WE would wish to discover the Plan of the Universe, and the means employed by the Eternal Architect in the execution of his magnificent design. We will first contemplate the System of which we make a part, and of which our Sun is the center. Thence we will ascend towards those Suns and those innumerable Worlds which are scattered through the immensity of space.

But, are the faculties of our nature equal to this? and what are the principles which ought to guide us in these researches?

The first that presents itself is derived from final causes. We suppose the existence of a wise and beneficent Being who presided over the formation of the World, and who is pleased to display his infinite perfections on this illustrious theatre.

Again we will found our hypothesis in the general laws of motion, whose effects are every where the same, and whose influence extends to the utmost limits of matter.

We will next proceed by the lamp of experience, consulting with care the observations deposited in the records of astronomy.

Finally, in order to supply the defects of experience, we will have recourse to the probable conjectures of analogy, conclusions which we will bequeath to our posterity to be ascertained by new observations, which, if we augur rightly, will serve to establish our theory, and to carry it gradually nearer to absolute certainty.

This is all to which weak and limited beings can pretend, beings who occupy a point, and last but a moment in this mighty edifice built for eternity.

THE

PART I.

SOLAR SYSTEM.

CHAP. I.

COMETS. PERMANENT STATE OF THE SOLAR SYSTEM.

NOTHING is more simple than the plan of the Solar System: we have only to conceive the Sun in one of the focuses of the eliptic orbits, which the planets and comets describe around him. We will bestow our chief attention on comets, as on them will depend all the merit of novelty to be found in the following theory.

Since it became known that the comets are bodies similar in their nature to the planets, and subject, like them, to regular periods and

 revolutions,

revolutions, the more sensible part of mankind have been freed from those superstitious terrors which they used to create in the minds of our ancestors. But to those groundless fears have succeeded others of a more legitimate origin, in as much as they seem to have the sanction of those very sciences astronomy and the phisiology of the Heavens, to which we owe our freedom from the former. If comets no longer foretell either war or famine, or pestilence, or the fall of empires, what are those partial evils in comparison of the dangers with which they threaten the integrity and safety of the whole globe?

When we contemplate the motion of those stars, and reflect on the laws of gravitation, we must easily perceive that their approach to the Earth might expose her to the most disastrous events; roll in upon her a second deluge, perhaps dissolve her in a deluge of fire, grind her to powder, at least, eject her from her orbit, carry off her moon, or, what is still worse, carry off the planet itself, transport her beyond the regions of Saturn, and consign her to a winter of several centuries, which neither man nor beast should be able to support. Even the tails of comets would be phenomena of no small

small concern to us, were those bodies, on withdrawing from the Sun, to leave them in whole or in part in our atmosphere.

On the other hand, it does not appear impossible that the comet should remain with us, and be forced to revolve round the earth, provided the mass of our globe should happen to be larger than its own. And, who will undertake to assure us that this is not the history of our Moon, as well as of the satellites of Jupiter and Saturn? For, in the Heavens, as on Earth, the weak takes the law from the strong.

All this, it has been said, is not only possible, but analogous to what actually happens. Does not Jupiter disturb the motion of Saturn? Does not the Moon cause the Earth to vacillate on her axis? And, does she not elevate and depress, alternately, the waves of the ocean?

Various considerations, however, ought to fortify our minds against the apprehension of those evils; and, in the first place, though they may be possible, they are by no means probable.

The same hand which projected the celestial orbs into infinite space, hath, no doubt, ascertained their courses, and will not suffer them to roam at large with the chance of deranging

ranging or destroying each other. The preservation of those vast bodies is of an importance incomparably greater than that of beings which procreate their species, and are re-produced from year to year. For the reconstruction of new worlds from the fragments of the old, myriads of ages would scarcely suffice. Hence, we every where observe the duration of beings generally proportioned to their mass. What is the life of a flower compared with that of a cedar, or the life of an insect with that of man.

We do no not mean to deny, that the heavenly bodies reciprocally disturb the motion of each other in their orbits; it is only, however, by slight affections, the necessary effects of their mutual attraction; whence we may infer, that those interferences were foreseen and wisely pre-determined, and, perhaps too, they contribute to the harmony of the system. In one word, I conceive that all those bodies have precisely the quantity of matter, the gravity, the position, the direction and velocity which are requisite, in order to their steering clear of these critical collisions. It may happen, for example, that a comet, in passing near Jupiter, should be drawn by that vast

planet

planet from the right to the left, or from the left to the right, for no other purpose but to avoid a concussion. Thus the exception itself returns into the general rule.

As to that of a comet being changed into a satellite, although we may admit the possibility of the fact, yet it supposes such a strange coincidence of chances as renders it almost incredible.

The whole satellites of our system revolve round their respective planets in the same manner as the planets revolve round the Sun, that is to say, from west to east. We will suppose then, that there are comets whose orbits have undergone a change; this change must have happened either in the comet's descent from its aphelion towards the Sun, or on its return from its perihelion; and, in order to its taking this direction of west to east, it would necessarily traverse the orbit of the planet either on the east in descending, or on the west as it returned But, as each time it was equally possible, that the contrary should happen, would it not be one of the most singular chances in the world, that the ten satellites of the solar system should all move in the same direction, whilst, to submit the point to a calculation of

its

its probability, it is 1023 to one that it should have happened otherwise?

Besides, as the orbits of all the satellites are but a very little inclined towards those of their planets, it is still less credible, that of so many comets which have passed near Jupiter and Saturn, and the Earth, they alone should have been converted into satellites whose orbits had this small degree of inclination.

How happens it, in short, that, of the vast number of comets, either of which we might have had for our Moon, we should have exactly hit upon one which accomplishes her revolution round her own axis, and her revolution round the earth in the same time, and which, for this reason, always presents to us the same hemisphere?

But these difficulties will appear in their full force when we figure to ourselves the manner in which the planets must have appropriated their satellite comets. Let us consider, for example, the circumstances the most favourable to a comet's entering and remaining in the orbit of the Moon. For this purpose we must suppose its motion more than twenty-seven times slower than that of the Earth, give to its aphelion the place of the full Moon, and make

it

it move in that position with nearly the velocity of the Moon; but then the elipse, which it ought to have described in its first orbit, becomes impossible, because the perihelion would fall into the body of the Sun. Would we draw back the aphelion of the comet beyond the place of the full Moon? This elipse would be still less inconceivable, unless we were to suppose the motion of the comet accelerated near the Earth; but, in this case, the very circumstance of its increased velocity would prevent its being detained by the Earth.

In fine, the whole hinges on these two suppositions: Either the comet lighted all at once on that path round the Earth which we see pursued by the Moon; and, it is impossible to conjecture how this should have happened: Or, it found it gradually, insomuch, that its orbit became fixed and permanent only by degrees. But this hypothesis is resisted by the known laws of motion; for, it is absolutely necessary that, at least in one point of its orbit, it should have the precise degree of velocity which corresponded to the distance of that focus from the Earth; but, thenceforward, it would move permanently round her, and its path would suffer no farther alteration. If, on the contrary.

trary, the comet should, in no point, move with this precise degree of velocity, it would be impossible for the Earth to command it by her attraction; at the utmost she would be able to produce a slight variation only in the comet's course round the Sun.

It remains to be remarked, that the Moon once drawn by the Earth's attraction round the Sun, no longer describes an ellipse, but a cycloid, in which she moves very little faster than the Earth, nay, even slower when in the place of the full Moon: whereas, the comets placed at a distance equal to that of the Earth from the Sun, move almost with double her velocity, which would still increase in proportion as they approached the Earth. Hence it is clearly demonstrated, that we can have no hold of comets, and, that without a miracle, they can never occupy the cycloid of the moon.

What ought to be our conclusion from all this? That the comets, the primary and secondary planets, were at all times what they are now; and, from the beginning of things, have pursued the same courses.

CHAP.

CHAP. II.

PRINCIPLES OF COSMOGONY.

IF we admit the existence of a Supreme Disposer, who brought order out of Chaos, and gave form to the universe, it will follow that the universe is a perfect work, the impression, the character, the reflected image of the perfections of its author.

Thus nothing happens, and nothing is what it is from undesigning chance; every thing is the effect of intelligence; every thing has its object; the means are subservient to the ends, and the ends to one another. We have not here an assemblage of detached parts, nor an assortment of shreds and pieces: it is a whole whose several parts cohere and tend jointly to universal order and harmony. In this order, the dust we tread under our feet, and the stars that shine over our heads, atoms and worlds are equally included.

But, as the universe is an extremely complex machine; the arrangement of the various parts of which it is composed, its preservation, and the play and energy of its springs, depend on an infinite number of general as well as particular laws. The most general admit of no exception. The exceptions attach on the detail; their number increases in proportion as the laws are specified and particularized, and thus become more and more limited and restricted by other laws. Hence the exceptions themselves form new laws and means employed for a higher end. Apparent disorder in the parts is thus absorbed in the order of the whole, and the small defects gradually vanish in the eye of the philosopher as he proceeds to view nature on a more extended scale.

Universal order and harmony consist in resemblances infinitely diversified, or in endless varieties referred back to a point of re-union. As here we propose to consider the larger bodies only which constitute, if I may say so, integral parts of the world, we shall pass over the varieties and exceptions, and confine ourselves to the most general exceptions and laws.

If the world is a whole, the heavenly bodies must act upon one another; there must be motion, and a law under which all motion is comprehended and controled Newton taught us this law when he demonstrated that all the globes in the solar system gravitate towards each other in the direct *ratio* of their quantities of matter, and in the inverse *ratio* of the squares of their distances. Whether this is or is not owing to an inherent virtue, a property essential to matter, the fact cannot be disputed; and, if the fixed stars are so many Suns, such as our own, we must conclude from analogy, that they are equally subject to the law of attraction, and that this law reigns over the whole material universe. Besides, perhaps there is no other equally fitted to introduce into it order, harmony and beauty. We shall see, presently, how much, from its fertile simplicity, it merited the choice of sovereign wisdom; a ray of which seems to have entered the mind of the great philosopher who made so wonderful a discovery.

CHAP. III.

THE POPULATION OF THE UNIVERSE.

IF we are convinced that every thing is formed by design, that every thing is in its proper link of the chain, that the world is the expression of the perfections of God, we will be inclined also to believe that all the heavenly bodies are inhabited, and, that universal space is replenished with as many globes as it can contain. We cannot bring ourselves to leave blanks and chasms in so perfect a work. In every situation that affords a point of view we will place an observatory and an observer.

Do we not already perceive here on Earth every thing full of life and motion, and nature busily employed in fructifying, in organizing, in animating matter? In a grain of sand, in a drop of water, we discover worlds and inhabitants; besides, our best microscopes only shew us the whales and elephants of those worlds; they are still far from reaching the insects. Yet men will insist, that all those vast globes which float with us round the sun, and which, like us, receive the benefit of his light and genial heat, are desert and destitute of inhabitants. I know no opinion less warranted by reason, or more unworthy of a thinking being.

If the heavenly bodies were immoveable, and constantly fixed in the same place, there would undoubtedly be room for them in much greater numbers. But their motion is necessary to the support, to the order, and perfection of the system; for the purpose of combining them in one whole, reciprocal gravitation was wanted, in virtue of which they act and react on one another. Hence it was requisite to assign them their paths, in such a manner as that each should accomplish and renew its period without disturbance.

Motion is performed in time and space; hence the plan of a well constituted world demanded a regular combination of these two things. Accordingly, nothing can be better conceived, nor more wisely proportioned. Every thing that is mortal possesses a principle of reproduction; whatever is liable to change, renews and repairs itself; changes in small bodies occur more frequently, and compensate, by their aggregate sum the great changes that happen to large masses. We cannot make a single step without destroying worlds, and without creating new ones. To build cities, to rear forests, years are required; the time of a revolution in the heavenly bodies increases with their masses even to ages and, perhaps, to ages of ages.

If from the center of our system we could embrace, with one glance of the eye, all the globes that revolve round the sun, we should see them in a state of strange disorder, the large mingling, pell mell, with the small, under a thousand different aspects, for which we should be unable to assign a reason; we should only perceive a confused group of masses thrown here and there without an object, and as it were by chance. But this perturbed spectacle would evolve into order the moment we made ourselves acquainted with the laws of motion. We would then see each of those bodies in the place and at the distance most convenient for it, each pursuing a route from which it must not depart, and which, as it should seem, had been traced out for it by rule and compass. Order and symmetry would result from apparent confusion; and such would be the case with respect to every thing that appears disorderly to us, provided we had *data* enough to refer those appearances to the whole of which they make a part.

There are therefore as many heavenly bodies as can find place, and move with freedom and security within the circumference of the universe. The whole of this space is allotted to orbits and globes which describe them: an observation which extends not to the solar system alone, but to all without exception. Each fixed star governs a world, as full and populous as our system, in proportion to its capacity; and those worlds

are

are as numerous as the bounds of the whole universe which contain them will permit. What a delightful, what an inchanting spectacle this immense machine! which goes on and maintains its infinitely diversified motions by the most simple of all laws, by the sole principle of gravitation. This is the master-piece of creative intelligence; an eternal object of admiration to men and angels.

CHAP. IV.

THE INHABITABILITY OF COMETS.

WE would wish that all the globes of the universe were inhabited; but, it is asked, are they all so constituted as to admit of this? Here comets seem to form such an exception as would go the whole length to destroy the rule; since to judge of their number from those, the memory of which is preserved, those bodies are vastly more frequent in the solar system than the planets; and, indeed, as will appear presently, there is no comparison between them in this respect.

How can we imagine, that living beings should exist whose domicile passes through the utmost extremes of heat and cold? The comet which appeared in the year 1759, and which returns sooner than any of those whose periods we yet know, supposes a winter of seventy years. But this is little compared with the heat to which the comets are exposed.

According to Newton's calculations, the strongest heat of the comet of 1680, was two thousand times greater than that of red-hot iron; and it would have required a period of 50,000 years to cool it down to its former temperature. Something, however, may be objected to this calculation.

1st. The greatest degree of heat that red-hot iron is capable of acquiring is not so easily determined. All we can know is, that it will scarcely exceed four times the heat of summer.

2dly. Newton did not extend his scale far enough on the side of absolute cold; a body which would take 50,000 years to cool, ought to require the same time to heat it up to that point.

In short, bodies are susceptible of a limited degree of heat only; and iron, once red-hot, if if you still continue to expose it to an intense fire, vitrifies and crumbles into ashes. If then the comet of 1680 bore a heat two thousand times greater than red-hot iron, it must have consisted of matter entirely different from any we are acquainted with: none of which could have resisted a heat of such astonishing force.

We shall form a more adequate idea of the actual heat of that comet by comparing the effect of the Sun upon it to that of a lense, or burning glass. We know that the heat of the solar rays increases in the inverse *ratio* of the square of the distance; thus, on the eighth of December, 1680, the comet being one hundred and sixty times nearer the Sun than our Earth, ought to have experienced 25,000 times a greater heat: so that if we suppose that our best burning glasses augment the force of the solar rays two thousand times, we would rather err on the side of excess than of defect, it will follow that twelve of these lenses would produce, I will not say a heat precisely equal to that of the comet, but, at least, it would be the heat which the Earth would suffer were she placed at the same distance from the Sun.

But, in fine, whether it be that the comet was composed of a more compact species of matter

matter, or owed its safety to other circumstances, it fortunately passed on in its course, and we have no doubt that its inhabitants passed on with it. They would require, we admit, a more vigorous frame, and a constitution differently formed from ours. But where is the necessity that all living beings should be made like us? Is it not infinitely more probable that, from globe to globe, there is a diversity of organization and temperament relative to the wants of their inhabitants, accommodated to the places of their abode, and to the vicissitudes of heat and cold, to which they are necessarily exposed. Have we not relinquished a similar prejudice, which led us to believe, that the torrid and frozen zones were uninhabitable? Do we find nothing but men on our own planet? And, if we had never seen fishes and birds, would we not, with equal reason, have concluded, that water and air were both destitute of inhabitants? Are we quite certain that fire itself has not its invisible inhabitants, whose bodies are formed of asbestum, or some other substance, impenetrable to that element? We may say with truth, that, of the nature of the beings who people the comets, we know nothing; but let us not deny their existence,

and

and, still less, the possibility of their existing.

It is true, the citizens of a planet, accustomed to a more mild and equable temperature, would be far from finding themselves at their ease, were they transported to one of those stars, subject as they are to the most violent changes of heat and cold; ourselves, for example, who, owing to our position, are, if I may be allowed the expression, the spoiled children of the solar system; but with bodies differently framed, we might be enabled to bear those changes, and, perhaps, find ourselves better than before.

Although what has been said might suffice to silence those who are for depopulating the comets, it may not be improper to consider the subject in another point of view.

How different soever the material substances of which the heavenly bodies are composed, there is one substance which, being diffused through the universe, must belong to them in common, I mean light. We will not infer from this, that the use and effects of light are every where the same. If with us it is refracted in the organ of sight, and paints the object in the bottom of the eye, it is not at all necessary

sary that the same thing should happen elsewhere. We still know so little of the nature and action of light, that we must not venture to pronounce respecting the effects it may produce on bodies of a different organization. It is possible that in some globes the people may have eyes such as we have, and that, in others, their acquaintance with external objects is acquired by organs and senses of which we have no idea.

Another question occurs equally curious, I mean whether heat is inseparably connected with light? Or, if light only serves to render it more active and efficient? Perhaps the earth possesses a central and original heat, which the Sun only excites and regulates, in a greater or less degree in the different seasons; or of which he repairs the waste occasioned by the continual evaporation of the solid as well as fluid substances of our globe. Should the comets likewise contain this central and latent heat, the changes of temperature they undergo in pursuing their long orbits would be gradual and less abrupt. But does not the inflated appearance of their atmosphere suggest an innate heat, which afterwards receives large accessions from their approach to the Sun?

The

The atmosphere of the comets may render them more essential services, though of a different kind. Let us carry our Earth into the proximity of the Sun, where was the comet of 1680; we should presently see the ocean, and all the waters on her surface leave their beds, ascend into the air, and form around us a lofty and thick column of vapour. This column, though it might not be able to save us from perishing, would, however, not fail to detain and quench the solar rays. It is found that his horizontal beams, in passing through our atmosphere are actually weakened by more than two thousand times. The atmosphere of the comet of 1744, which reached nearly eight thousand leagues in height, would therefore reflect and intercept several thousand times a larger portion of rays, and form a canopy in condition to screen the comet and its inhabitants.

If the comets contain fluid substances similar to water, their central or native heat may be such as to preserve them in a liquid state at their greatest distance from the Sun; while, in his vicinity, the same fluid, by being converted into vapour, may afford them the salutary shade of which we have just spoken.

What

What proves besides that their atmosphere actually intercepts and reflects towards us a certain portion of the rays, is, that it is almost equally visible and luminous with the body of the comet. Seen from the Earth, the comets shew none of those phaces or aspects which we observe in Mercury and Venus. The comet's atmosphere opposed to the Sun is no less luminous than that which is turned directly towards him. Hence night with their inhabitants is but a twilight, nor is it inferior in brightness to what we call *day*. In the comet of 1744, when it was in the vicinity of the Sun, this light resembled that of our morning, when the Sun is half a degree above and below the horizon; nay, it was even brighter. The atmosphere of this comet had a diameter ten times longer than that of the comet itself; how much then must it not deaden the rays of the Sun, by dispersing them all over the surface of the comet. This is a great deal; but it is not all, since many of those rays would never reach the surface.

The dispersion of the solar rays in the comet's atmosphere, has probably no other effect than to heat and expand it; but heat tends always

ways upward, and makes its escape to cold regions, We may presume then that it hurries along with it, in its rapid progress, a part of the atmosphere, and particularly a portion of the tail: for the tail is subject to very remarkable changes. In proportion as the line in which the comet descends approaches to a straight line, the tail lengthens: in returning from its perihelion it becomes shorter, and, in a word, continues to diminish as the comet ascends; an appearance which a decrease of heat alone can account for.

It may be asked, what becomes of the matter of which it was composed? Perhaps the Sun collects his atmosphere from the remnants of those lost tails. But however this may be, their materials must remain in our system; and as they gravitate towards the Sun they will somewhere find their balance. Is it impossible that a column of this stuff diffused through the ether, should be destined to furnish comets, on their passage, with a supply of provisions, and that at a time when they are about to fall in their temperature; and thus, perhaps, they lose and recover their tails alternately, in such a manner and proportion as is best suited to the actual circumstances of the comet?

CHAP. V.

NUMBER OF COMETS.

THE history of the heavens, or, which is the same thing, of astronomical observations, informs us that the number of comets exceeds that of the planets. Halley's table, in which we only find the comets whose course had been observed to his time, contains 24, but which we ought to reduce to 21, because two of them make properly but one, which appeared twice: and three others, in the same manner, make but one, which appeared at three different periods.

Among these twenty-one, we have two only whose perihelion is farther removed from the Sun than the mean distance of the Earth: all the remaining nineteen have it between the Earth and the Sun: two of these last pass between the Earth and Venus, eleven between Venus and Mercury, six between Mercury and the Sun.

A small degree of attention to the position of the Earth, and that of her orbit, will convince

vince us, that the comets which shew themselves to us are nothing compared with those that escape our observation,

The comets which descend below Mercury are almost all visible, either as they approach their perihelion, or as they ascend towards their aphelion. The only case in which they may conceal themselves, is, when the extended part of their orbit lies beyond the Sun, relatively to the Earth, and when they have at the same time a southern latitude in the situations where otherwise they might be visible. Then they are scarcely to be observed, except on the other side of the equator. In our climates they skulk under the horizon at the time we should have the best chance of observing them.

We see likewise such as pass between Mercury and Venus with great ease. Their light is extremely vivid; their enormous tail draws out still more in length on their approach to the Sun, as was observed to be the case with that of 1744; and their progress round him occupies the space of some months, a period sufficient to enable us to observe them, either in the evening or the morning, whatever be the Earth's position in relation to them and the Sun.

 The

The case of comets whose perihelion is as remote from the Sun as our Earth, or at a still greater distance, is quite different; they have a fainter light, and the tail is shorter; near the Earth their apparent motion is at times extremely rapid, insomuch that they move at the rate of ten, and sometimes twenty degrees a day, and even more. They continue visible only during some days, or at most, some weeks: besides, it is necessary that the Earth should be in the most favourable position in regard of the comet. Their size quickly diminishes, and they hasten to withdraw from our view. The comets of this order, provided we assign them long elipses, would employ, between their departure and their return, a period that must be measured by ages; news which will induce us to expect them but seldom.

We may rank in this class almost all the comets which shine for a few nights only; a space frequently too short to afford us an opportunity to determine their orbits. Some of them escape us during thick hazy weather, and once they are out of view of the naked eye; it is a matter of the greatest accident gent if we are able to catch them with the telescope.

As the prodigious bulk of the comet's atmosphere darkens its lustre, it is hardly possible to see such as sojourn above the sphere of Mars; and even those which we have had time enough to observe, disappear so soon as they get to the height of that planet. The comet of the year 1759 passes five years in the sphere of Saturn, while we see it only about as many months. All this agrees perfectly with Halley's table, where we find but two comets out of twenty-one whose perihelion is at a greater distance from the Sun than the Earth is from the same body.

This table being constructed on observations which we owe to accident, lays but a weak foundation for judging of the possible number of comets. If we suppose, that, of all the comets of our system, that of 1680 has its perihelion nearest the Sun, we can conceive five or six others equally near him, and twelve at double the distance. This is a moderate estimate; for there is nothing to hinder our making comets pass by hundreds, perhaps by thousands between Mercury and the Sun. Let us begin, however, by Halley's table, and compute from it the number of comets we may assign to the solar system.

In order to restrict our terms still more, we will admit of no perihelion beyond the regions of Saturn; though, since Saturn's distance from the nearest fixed star exceeds his distance from the Sun by more than fifty thousand times, we have no reason to confine ourselves for want of room.

We require, in the second place, that the comets have such an arrangement as that they shall never meet nor disturb each other in their career. For this purpose their orbits must not intersect each other in any one point; and, further, these orbits must not be regarded as geometrical lines; though we will conceive the sphere of each comet's activity to be so defined, as to restrain it from making irruptions into the spheres of others, and committing such disorders as would unavoidably arise from violent aberrations.

This being premised, we proceed to our calculation :—

If we consider, first, the six comets which Halley's table shews us between Mercury and the Sun, I would ask in what *ratio* we ought to suppose their number increases? At first sight we should imagine that it is in the *ratio* of the cubes of the distance of perihelions from the Sun, because we can thus distribute perihelions in each spherical space which we conceive about a given point; and this would answer, in fact, did the comets remain immoveable, constantly attached to their perihelions. But our second term requires that they should have the freedom of motion, and excludes the intersection of orbits; consequently, it opposes an increase in the *ratio* of cubes, and reduces it to that of the squares of the distances.

Though we had no right to expect that this law should exactly obtain in Halley's table, we, nevertheless, find it verified in respect of the comets which have their perihelions nearer the Sun than Venus; for the table gives seventeen comets between Venus and Mercury; and six between Mercury and the Sun; a difference which is nearly in the proportion of three to one, or in that of the square of the distance of those two planets from the Sun.

The square of the distance of Saturn exceeds the square of the distance of Mercury about six hundred times; and, consequently, if we every where place perihelions at the same distances, we shall then have six times six hun-

 dred,

dred, or 3,600 perihelions with their comets in our system.

But this number deduced from Halley's table is evidently by far too small, as may be easily shewn. Let us recollect, that we can see none of the comets which have their perihelions beyond Mars. The plane of Mar's orbit is forty times smaller than that of the orbit of Saturn; and, therefore, of these 3,600 comets, we could see a fourth part only, that is to say, ninety. Now we learn, from history and tradition, that the number of comets seen (I do not say observed) exceeds two hundred without noticing meteors, which, sometimes, have been confounded with those bodies. On the other hand, if we consider how many comets may be supposed to have passed without observation, whether in the day-time, or in a clouded state of the skies, or by reason of their southern latitude; all these circumstances, I say, taken into account, we may boldly double two hundred, in order to come at the number of those which fall within the field of our view. Such as have appeared more than once may be left out of the reckoning. Besides, that they are not seen every time they return, their return happens but very seldom.

seldom on account of the magnitude of the greatest part of the comet's orbits; probably there are comets which have appeared but once since the flood: in short, though their number was to be estimated much higher, it would be amply compensated by that of comets which escape our observation from the difficulty of finding them; for there scarce passes a year when we should not see comets, did we know when to expect them.

From the year 1500 to the 1600, there appeared more than forty comets, not one of which has, it should seem, been seen again during this long period; hitherto we know of none except that of 1759, whose revolution is less than a century. This would give us, for four centuries, 160 comets; let us deduct 60, if you please, for such as may have been seen more than once, there will remain a hundred. Upon the supposition that we see the third part only of those that might be seen, the triple of this number gives us three hundred. These three hundred taken forty times, that is to say, as often as the sphere of Saturn surpasses that of Mars, which sets bounds to the visibility of comets, will produce 1200 instead of 3,600, the number calculated from Halley's table.

 But

But we take things with a great abatement if we reckon only 300 visible comets; there is reason to believe that their number amounts to some thousands; at least the table, by the different positions it assigns to orbits, and the chasms it leaves to be filled up, gives countenance to this opinion.

The following is a more just estimate:—

Taking for our basis the comet of 1680, whose perihelion was more than sixty times nearer the Sun than Mercury, we may place between Mercury and the Sun the whole 3,600 perihelions which we had dispersed all the way to Saturn; for this number is precisely the square of 60. In this manner we shall have six hundred times as many within the bounds of Saturn; or, in other words, above two millions. In short, as one may suppose on the side of the perihelion of 1680, two or three similar perihelions, a very moderate estimate, will give motion in our solar system, to at least five hundred millions of comets.

All these comets, agreeably to our hypothesis, would have their perihelions nearer the Sun than that of Saturn. But what is to prevent our conceiving others vastly more remote even beyond the sphere of that planet? Space ex-

pands

pands in proportion to its distance from the Sun; and, likely, it is in those far situated regions where float the comets of the largest size; comets, possibly, with satellites whose enormous masses and tremendous spheres of activity forbid a nearer approach to the Sun, in whose bounds space is more confined, and requires to be managed with a sort of œconomy.

How prodigious the number of comets! What then becomes of the planets? They seem to be lost amidst the innumerable celestial orbs that surround the Sun. How small a part of our system is known! What a pitiful molehill is our Earth; and, how insignificant are we—we who creep so proudly on her surface!

CHAP. VI.

THE COMETS COMPARED WITH THE PLANETS.

UPON what grounds, we shall be asked, do we croud the solar system with such an immense number of comets, while that of the planets is so inconsiderable? The answer to this question will be more satisfactory when we have compared them, and pointed out wherein they agree and wherein they differ.

The

The comets and planets are equally inhabited and equally perform their revolutions round the Sun.

The first circumstances of difference that strike us are the tail of the comets, and the great magnitude of their atmosphere; but, as the tail draws out in length, and the atmosphere swells so exceedingly in bulk only on their approach to the Sun, and in consequence of his heat, these appearances are nothing but the temporary effects of heat; and they last only during a few months of their long period. We are not, therefore, to suppose that the inhabitants of comets are drowned in eternal fogs and vapours which prevent their observing the phenomena of the heavens. It is true the atmosphere of the earth does not expand in the same degree, but it is continually around us; and, for a very considerable proportion of our lives, the sky is involved in clouds; but are we, thereby, disabled for exploring and measuring the Heavens?

Another circumstance of difference, which is the cause of the preceding, regards the orbits. The planets describe elipses more nearly approaching to circles; whereas those of the comets are extremely eccentric and extended. This, however, is of little moment since it only

only respects a greater or less degree of curvature. The circle is an elipse whose two focuses coincide Possibly the orbits of our system exist, in gradation, by numberless shades of difference from the most eccentric to the circular elipse.

It is true we see comets in oblong elipses only; but this is owing to our seeing but a short way. Saturn is the last planet we have hitherto been able to discover: all the comets which do not descend below the sphere of Mars are hid from our view; and, in order to their shewing themselves distinctly, they must approach the Sun at least by one half nearer than the Earth. This would lead us to conceive, that of all the bodies of our system, we see those only whose orbits hold the two extremes in the class of elipses; or, in other words, whose elipses are the most and the least extended.

The length of the periods of comets proves the vast prolongation of their eliptic orbits. Among the comets we have had access to examine, that of the year 1759 has the shortest period; it returns to us again at the end of seventy-five years. The cubic root of the square of this number gives its mean distance

 from

from the Sun, which exceeds that of the Earth by seven times and three quarters. This number doubled, or thirty-five and a half, expresses the length of the great axis of its orbit; whence we may infer how much these orbits ought to contract when the perihelion falls between Mercury and the Sun, and for a still stronger reason when their periods are of a longer duration. Let us suppose a comet which has its perihelion at the distance of the Earth; while its periodical time is seventy-five years only, the great axis of its orbit will, nevertheless, exceed the small axis by three times. The supposition, however, is extremely arbitrary; such a comet would require ages to accomplish its revolution.

Orbits take more of the circular curve in proportion as their perihelions recede from the Sun; and the last orbit of the solar world can differ but little from a circle. We may presume that some of these orbits rise above Saturn; at the same time our system has its limits, and the sphere of our Sun's activity, how extensive soever, reaches not to infinity: the most remote of the comets must still gravitate towards the common focus; it must, therefore, keep at a proportionate distance from the

the systems contiguous to ours in such a manner that its gravitation towards them may be considered as null. The fixed star nearest to us is five hundred thousand times farther from the Sun than is the Earth. If we were to place the last comet at the thousandth part of this distance, its aphelion would be five hundred times more remote than ours; if it described a circle, this distance would be a semidiameter of its orbit, and, consequently, it would complete its revolution in a period of 11,180 years: a period which would scarcely be abridged by two thirds were we even to suppose that the comet should descend all the way below Mars.

Another difference. The planetary orbits are nearly in the same plane, and almost in the plane of the Sun's equator: on the contrary, those of the comets are variously inclined, as well in respect of one another, as in respect of the Sun's equator.

We say that the planetary orbits are nearly in the plane of the Sun's equator, leaving out of our consideration the angle of seven degrees and a half, which it makes with the ecliptic. But, do the planets derive any advantage from this circumstance?

If

If we could suppose that light is unequally distributed over the surface of the Sun, or that it suffers there any considerable alterations, the heat emanating from his orb to be diffused over the planets would be subject to the same accidents. Consequently, by the Sun's rotation on his axis, in virtue of which he presents, successively, different parts of his surface to the planets, his light will be more uniformly dispensed if they are in the plane of his equator, than if the plane of their orbits were inclined to it under a right, or any other angle of considerable magnitude. The comets are the more indifferent to this advantage, that they are formed to undergo every sort of change in respect both of light and temperature.

Again, is it not possible that the heat of the Sun, abstracted from the light, is propagated only in the direction of the solar atmosphere, which, perhaps, contributes to its intensity? But the Sun's atmosphere follows the plane of his equator; in this case it is evident, that, in order to have the benefit of it, the planetary orbits ought to be in the same plane.

The last difference.—All the planets, including satellites, revolve from west to east; while the comets roll through the Heavens in all directions,

directions, and cross each other in every possible way; the reason of this is not very easily discovered. Is it for the purpose of avoiding hostile interferences? Is it that Jupiter and Saturn have turned some of those bodies out of their course? In Halley's table we find the number as equal as possible of comets which move from east to west, and of those which move in a contrary direction. But this table must be infinitely more complete before we can rest our judgment upon it with certainty; an advantage which time and observation may give to our posterity.

But what we discover in the mean time, is the absurdity of men who pretend that the planets are nothing but comets diverted from their original course and fallen in temperature; a notion which is refuted by the same arguments we employed above in respect of the satellites. There are, in all, sixteen planets, primary and secondary in our system; how happens it that not one of them moves from east to west. There is 65,536 to one that this should have been the case, at least, in a single instance. It is infinitely less probable still, that these sixteen comets should have wandered from their ancient paths in the precise manner

that

that was necessary in order to their entering new orbits situated in the same plane, and, in a plane which is, in common to them, with the Sun's equator. Nothing here savours of chance; every thing indicates design and regulation. The heavenly bodies are at this day what they were from the beginning.

Having determined the circumstances in which the planets and comets differ, we proceed to examine why there are so many of the one description and so few of the other.

CHAP. VII.

WHY SO MANY COMETS AND SO FEW PLANETS.

THAT the comets are by far more numerous than the planets is a fact, the reason of which we proceed to investigate: and this is a task the more incumbent on us, that we increase the number far beyond what is warranted by the discoveries hitherto ascertained.

According to the idea we have formed of the solar system, it ought to be as populous as possible. For this purpose we give to it as many moving

moving bodies as it can contain, without confusion and without disorder. Hence the most perfect plan of our system will be that into which enters the greatest number of orbits, all separated from one another, and which in no one point intersects each other. If then we should be able to prove that the orbits and comets correspond to this end better than those of the planets, the reason of their superiority in point of number, must be seen and admitted by minds of the most ordinary capacity.

The question, therefore, comes shortly to this, which of these two species of orbits the eliptic, or circular, can be conveniently introduced in the greatest number into the solar system?

If all the bodies in our system described circles, the law of gravitation would require that the Sun should occupy their common center, or, in other words, that all those circles should be concentric: and we must not forget, that under the orbits of planets and comets is comprehended a considerable part of their sphere of activity.

Thus the system would present the aspect of a hollow sphere, with the exception, that the circles not being permitted to touch each other, the exterior would be always larger than the interior, and would increase in magnitude in proportion as they were removed from the center. For, if they were joined in one another, as the Equator is in the Colures, they would have certain points of intersection, which we have expressly excluded from the system.

But in what *ratio* would the number of these circles or circular orbits increase? It could only be as their distance from the common centre. And whether they are placed in the same plane, or inclined under a certain angle, is a matter of perfect indifference, since they must remain for ever concentric, and consequently the empty spaces be equally lost.

It will be recollected, that by placing six perihelions only between Mercury and the Sun, we found 3,600 eliptic orbits between the Sun and Saturn. Here, however, we should scarcely find 150 circular ones.

We easily perceive that the great inconvenience of circles is owing to this circumstance, that they must be concentric; an inconvenience which does not occur in the case

of

of elipses; and so much the less in proportion as they are oblong, like those we have seen described by comets passing between Mercury and the Sun. For the Sun is not in their center, but in one of their focuses. Hence it is, that we cannot only imagine several of an equal magnitude, but we may interlace them a thousand different ways, and make them diverge above, below, and on each side, towards all the regions of the world. In order to render the idea still more sensible, we have only to construct a sphere composed of eliptic bands or fillets, and compare it with another made of those of a circular form.

It being then unquestionable that elipses supply orbits in infinitely greater abundance than circles do, we will cease to be astonished that we should people the heavens with so many legions of comets; and instead of being surprised that the number of the planets is so small, we shall rather ask why we have any of them at all. One is disposed to imagine, that for the good of the world, not one of them should be suffered to exist. By what title, in fact, can we pretend to hold our place? We may alledge, for want of a better reason, that good order, and the regular variety of system, required that, among others, there should be globes whose inhabitants might enjoy a more equable temperature. Perhaps also, room was found for a few circles in the interstices of the eliptic orbits, and that we are here only by way of filling up the empty stowage.

Here we may again observe, that it is not without design that the orbits of the planets are situated in the same plane. It was so contrived in order to leave a freer career to the comets above and below this plane, to simplify the intersections of the planes, and to multiply the number of comets.

For our further satisfaction, let us suppose the contrary of this. Let us suppose, I say, that the whole of the planetary orbits were inclined to one another: that the Earth remaining in her own, the planes of the orbits of Mercury and Venus should cut each other at right angles at the pole of the ecliptic, and should be cut in like manner by the others under different angles. The six planets will thus occupy six planes, as to either of which a comet must not approach the Sun nearer than the planet which moves in it, because the comet must not be permitted to traverse the planet's orbit. Jupiter and Saturn will exclude so

many

many more comets, that in the vast planes embraced by their orbits, we might have placed a greater number of those long elipses, which, from the little room they occupy, are so convenient for increasing the number of comets.

Let us replace the planets in the plane of the zodiac, there will be nothing lost but this plane; all the rest may be filled up with elipses. And of the elipses, which we may place in the same plane, we may lengthen the interior, and widen those that inclose them, in proportion as they become distant from the common focus, and thus provide a free passage across their intervals for comets situated in other planes.

As the comets which traverse the plane of the ecliptic cut it in two places, it would be convenient to have one of the points of intersection at a greater distance from the Sun than the other. Were we to place them at equal distances they would both be too near the Sun, where space is contracted, and must be managed with prudence; whereas if we place one only of these points near the Sun, that equally distant from him on the other side, will admit a new comet, and by this means their number would be doubled. For, as to remote

remote intersections, we have no difficulty to apprehend from want of room; we may draw back the greatest part of them even to the higher planets, where they have ample scope; and from these planets all the way to the fixed stars, there is a wide field for the reception of orbits.

It seems extremely probable, that the planets are so very distant from one another only to leave intervals of passage for the comets. And as in the elipses, which are at once extremely long, and extremely obliquely inclined, the orbitical intersections happen at the greatest distances from the Sun, hence we perceive the reason why Saturn, and Jupiter, and Mars, leave the widest spaces between one another. If there are planets beyond Saturn they ought to be still farther separated, since in those regions the points of intersection are by far most frequent.

In a word, the whole agrees, and seems to be arranged conformable to our idea; reasons of physics and cosmogony tend equally to its confirmation, Here then is the triumph of the Newtonian law; so wonderfully does it coincide with the principles of cosmogony, which the Supreme Architect must have observed,

served, with the order, the variety, the periodical motions of the heavenly bodies, and with the population of the solar system. It provides for every thing, and, probably, the whole taken together, constitutes a *maximum*, in which obtains the highest possible perfection.

The same beautiful combination, no doubt, implies the motives of preference given to the law of gravitation over all others in the organization of the world; motives which hitherto have not been fully unfolded. We see, in fact, the high prerogatives of this law above every other the imagination might suggest. If, for example, the heavenly bodies described, instead of elipses, spiral lines; each spiral, not to mention other inconveniences, would occupy an intire plane, and its contour hampered near the Sun, would not admit the intersection of other spirals. Still, however, this will not prove the necessity of elipses; if ever this proof shall be discovered, it will probably be through the resources to which we have already referred.

All those discoveries, which have been, and in process of time may be made, exalt the glory of the immortal Newton, who derived this

this admirable law from the depths of his own genius. His name, for ever revered and sacred on earth, ought to soar through all the regions of space which he has measured, through all the globes which he has weighed, and be echoed in the music of the celestial spheres.

CHAP. VIII.

THE TABLE OF HALLEY.

OUR distribution of the comets, and the plan we have thus sketched of the solar system, cannot be verified by experiment. In order to this, we have occasion for a much larger stock of observations; and of so many millions of comets which we assign to our world, Halley's table presents us with twenty-one only that have been examined.

But would it not be greatly in our favour, if, in these twenty-one, which chance submits to our observation, we should perceive the visible traces of the rule we have adopted, in distributing

distributing comets through the solar heavens? The determining the orbits of comets hinges on six circumstances. Now, if in the twenty-one observed comets these circumstances should be such, or nearly such as that, thence we discover that the position of orbits is as much varied as possible, and contrived in the best manner for augmenting their number, and consequently for promoting the population of the system: are we not warranted in believing that the rule we employ is general, and will become more and more evident from subsequent observations?

For we will suppose that the system is framed according to a different law. These twenty-one cases might no doubt be so many deviations from the general principle; but by what incredible chance must it have happened that they should coincide exactly in the six points which enter into the rule that I have adopted? Upon such a supposition, it should seem that among many millions of comets, a selection had been made of twenty-one, which constitute exceptions so accurately defined as to suggest the existence of a different law?

The

The six circumstances by which the orbits of all comets are determined are the distance of the perihelion, the inclination of the orbit to the ecliptic, the position of the lines of the nodes, the latitude of the perihelion, the helio-centric longitude, and the time of the year when the comets traverse it. To which may likewise be added the direction of the motion of the comet.

I say then, that in the twenty-one comets of Halley's table the variations of all these circumstances nearly quadrate with the plan we have projected; and if it suffers any exceptions, either they compensate each other, or we can assign the cause of it. And after all, ought we not to be astonished that the exceptions are so very inconsiderable.

In the first place, the number of perihelions increases as the square of the distances, such as we presumed. It increases, I say, in this *ratio* in the twenty-seven comets which pass between Venus and the Sun, and consequently in such as we have the best opportunity of observing. As to those that have their perihelion at a greater distance, we have already seen that there are so many reasons for their escap-

ing

ing us, that the four in Halley's table can scarce be regarded as an exception; and since from Venus all the way to the Sun, all the perihelions fall under the rule, it is reasonable to conclude that the same thing takes place to the very extremities of the system.

The inequalities which occur in the heliocentric longitude are also compromised, when we take into account the causes which facilitate and obstruct our view of comets; hence it is that it falls twice in the northern for once in the southern signs of the zodiac.

It happens on the contrary, though for a similar reason, that the number of comets seen during winter is the double of those which have been observed during the summer months. Nothing is more natural, considering the length of the winter nights.

The position of the line of the nodes is distributed pretty exactly on the zodiac, by every four signs. Eight of these lines correspond by the ascending node to the first four signs, six to the next four, and seven to the four last.

The latitude of the perihelions, or their elevation above the ecliptic, increases as the zones of the sphere, or as the sine of the latitude, such

such as we ought to have it, in order to distribute them equally on the sphere.

Of the twenty-one comets in the table, there are eleven, and consequently nearly one half retrograde; of the eleven, five are southern and six northern; and of the ten which have a direct motion, five are southern, and as many northern. In the one and the other the angle of inclination, and the distance of the perihelion, are as much varied as possible.

I reserved for the last the inclination of the orbits, because it admits of some difficulty.

Were we to judge from Halley's table, we should be of opinion, that the orbits of comets are inclined to the ecliptic under all sorts of angles; and that as to them all inclinations whatever are equally admissible. There are some in this table which form, with the ecliptic, an angle of from five to six degrees only, and consequently not greater than that of the orbit of Mercury, and which Kepler estimates at 6 deg. 54 min. But our system supposes, that the great are much more frequent than the small inclinations, because the former tend to promote a still greater diversity in the situation of the orbits; and we could demonstrate, that, in order to answer this end, the angles of inclination

nation ought to be quite differently distributed in the table, which therefore, in this respect, will be found faulty. To reconcile this deviation with the rule, it may be said that, perhaps, the equal distribution of the perihelions does not allow that of the poles of the orbits, which would ascertain the position of these orbits. One may suppose likewise, that the eliptic, or the plane of the planetary orbits, has this peculiarity, that it admits of inclinations of the very smallest dimensions. But our surest course is to recur again to the difference occasioned by the difficulty or facility we meet with in observing the comets.

When the perihelion lies south, it the more easily eludes us by skulking under the horizon, during the intervals we might see it, that the angle is large under which its orbit is inclined; whereas when the perihelion is north, the magnitude of the angle of inclination, raising it far above the horizon, brings it more within the field of our view. Now, if we consult Halley's table, we shall find that, generally speaking, the small angles of inclination belong to the southern comets, and the large ones to those of the north; a difference solely owing to this circumstance, that it is much

much more difficult to see the former, when the angle of their inclination exceeds a certain size.

Upon the whole, it appears, that Halley's table, incomplete as it is, corresponds, much beyond our expectation, to the plan of arrangement we have introduced into the solar system, and gives good reason to hope that it will be found to correspond more and more, in proportion as time and experience shall render it more perfect.

CHAP. IX.

PARABOLICAL AND HYPERBOLICAL ORBITS.

WE are still far from having enumerated all the wonders which the law of gravitation is found capable of effecting; wonders which the human understanding will never be in condition to exhaust. They afford, however, an agreeable subject of meditation, which exalts the energies of the soul, and renders the spectacle of nature peculiarly interesting.

The

The curves which the law of attraction may oblige the heavenly bodies to describe, are not confined to the elipse and circle; the sections of the cone are equally within its province, because they all have a focus wherein attraction may reside.

It is well known how much these sections are analogous to each other; how little is required to convert either the circle or the parabola into the elipse, and how easily this last passes into the hyperbola. Let us say, for example, that Saturn begins to perform his revolution in a perfect circle, his circular motion would be of very short continuance. The The first large mass that should approach him would draw out his orbit in length; his first conjunction with Jupiter would force him to resolve in an eclipse.

The same would be the case with parabolic orbits; it is physically necessary that, sooner or later, and at no great distance of time, they should change their nature, and become either ecliptic or hyperbolic. Let us see what would be the result of these transmutations.

I shall suppose that a globe in our system begins to describe a parabola. If this curve closes and returns into itself, the globe will remain with us, and acquire a periodical motion round the Sun.. If on the contrary, it extends its limits so as to become an hyperbola, the globe will recede more and more from the Sun, and leave us never to return.

Were we to pursue the fugitive in idea, we should see it perhaps at the end of some thousands of years, flit along the frontiers of our system, and dive into a neighbouring world. The central body of this world would then exercise its attraction over the new visitor, and give a curvature to his orbit. From that moment one of two things would happen. Either its path would change into an elipse, a change more or less easy in effect, according as the hyperbola it described at his arrival was more or less an approximate of the parabola. In this case, its travels would be at an end; it would remain to the system by right of conquest, and proceed to make regular revolutions round the dominant star of that system. Or, perhaps, after passing its perihelion, and having paid its court to the reigning star of those realms, it would again resume its hyperbolic progress, and, approaching the symtote, withdraw in a straight line,and proceed to visit other worlds.

Thus we can conceive comets which, being attached to no particular system, are in common to all, and which, roaming from one world to another, make the tour of the universe. I ask, why, in the infinite variety which the Creator has introduced into his works, such globes should not have a place? Their destination may embrace the wisest purposes, concerning which we may be allowed to speculate.

I love to figure to myself those travelling globes, peopled with astronomers, who are stationed there for the express purpose of contemplating nature on a large as we contemplate it on a small scale. Their moveable observatory cruizing from Sun to Sun, carries them in succession through every different point of view, places them in a situation to survey all, to determine the position and motion of each star, to measure the orbits of the planets and comets which revolve round them, to observe how particular are resolved into general laws, in one word, to get acquainted with the whole as well as the detail.

We may suppose that their year is measured by the length of their route from one Sun to another. Winter falls in the middle of their journey; each passage of a perihelion is the return of summer; each introduction to a new world is the revival of spring; and the period of quitting it is the beginning of their autumn. The place of their abode is accommodated to all their distances from the fixed stars; and the different degrees of their heat make the fruits and vegetables designed for their use, blossom and ripen.

Happy intelligences, how excellent must be the frame of your nature! Myriads of ages pass away with you, like so many days with the inhabitants of the Earth. Our largest measurements are your infinitely small quantities; our millions the elements of your arithmetic; we breathe but a moment; our lot is error and death; your's science and immortality.

All this is agreeable to the analogy of the works of creation. The frame of the universe furnishes matter of contemplation as a whole as well as in each of its parts. There is not a point that does not merit our observation; this magnificent fabric is portioned out in detached parts to created beings; but it is in the unity of the whole that sovereign perfection shines; and, can we suppose, that this whole has no observers? The imagination, indeed, after so

sublime

sublime a flight, may be astonished at its own temerity: but, in short, here the cause is proportioned to the effect, and there is nothing either great or small in immensity and eternity.

END OF THE FIRST PART.

REMARK.

REMARK.

HERE we shall take the liberty to suggest an objection to this brilliant idea of Mr. Lambert. If the life of his astronomical observers corresponds to the vast career their globe is destined to perform, we easily conceive that they ought to enjoy a magnificent spectacle and infinitely diversified; but, as their observatory changes its place every instant, and never returns to the same point again, we cannot so easily imagine how those observers should have it in their power to take positions, determine situations, or measure orbits; it does not appear by what means they could contrive either to regulate their pendulums, or ascertain the first elements of an astronomical observation. We should be almost tempted to believe, that, by reason of their seeing too much, they would actually see less of the mechanism of the universe than ourselves.

PART II.

UNIVERSAL SYSTEM.

CHAP. I

OF THE MOTION OF THE FIXED STARS.

IT is generally agreed, that the fixed stars are so many Suns which dispense light and life to as many systems, and render the same good offices to the planets and comets in their dependence, as our Sun renders to the world of which he is the head.

All those Suns have been supposed immoveable, or with a motion round their centre only. But here a new scene will open presently:

In running the eye over the starry firmament, we look in vain for order and harmony. Stars of all magnitudes are mingled together: some of the largest crowd apparently upon each other; while, in other regions of the Heavens, we are presented with a void where here and there stars of the sixth magnitude are seen to twinkle but faintly. In that luminous arch which embraces the heavens, and which is known by the name of the milky way, stars seem to touch and press on one another. There they appear scattered like drops of rain in our atmosphere which refract the colours of the rainbow. Compared with this, the rest of the heavens is but a desert.

Here then every idea of order and harmony vanishes. We have seen, in the preceding part of this work, that we should meet something of the same kind, could we take in at one glance of the eye all the bodies that are in motion in the solar system; but we have seen, at the same time, this apparent confusion evolve into order before the eye of the understanding. Let us judge of the celestial vault by analogy, and combine, as we have done above, time and space. This we shall be in condition to do the moment we conceive the fixed stars to be in motion; the only method by which we can banish confusion from the heavens, and introduce the reign of order. The law of attraction, which extends its dominion over every atom of matter, suffers nothing within the

the universe to be in a state of absolute rest: Motion obtains every where; all bodies of whatever description gravitate one towards another; all the wheels in this vast machine are going round; nature tolerates no dead and useless masses. The universe is a whole whose different members or systems can only be combined by reciprocal action and re-action, from which motion results as a necessary consequence.

In order that motion should be regular and durable, it is necessary that the centripetal should balance the centrifugal force: without this equipoize, the heavenly bodies obeying the law of gravitation only, must gradually approach each other, till, at last, they would meet and the world return into chaos.

From the centrifugal, combined with the centripetal force, results motion round a centre in one of the curves of conic sections. Thus, in the regions of space, all the fixed stars have their orbits assigned them, which they pursue, leading in their train a retinue of planets and comets; precisely in the same manner as we drag our Moon along with us round the body of the Sun, and as Jupiter and Saturn drag after them their respective satellites.

If we could demonstrate that every body which revolves on its axis must likewise move in an orbit, we could no longer refuse this last motion to our Sun, since we know he has the first. Probably the mechanism of the world requires the combination of these two motions, though we do not distinctly see the cause of it. What we know is, that the Sun actually shifts his place, for his centre does not always coincide with the centre of gravity common to the whole system. However, as the circle he thus describes is extremely small, we are not at liberty to conclude that the centre of gravity itself advances in an orbit. Thus far therefore we must confine ourselves to the reasons mentioned above.

The motion of the fixed Stars must in process of time change their apparent distances, and consequently become observable. It is true they may traverse spaces of immense extent before their apparent place appears to be altered, even by some minutes. The discovery of such change of place will depend in a peculiar manner on our observing the distance which those of the first magnitude hold, relatively to one another at different periods, because they probably are the fixed Stars most contiguous

contiguous to our system. Upon comparing the observations of Hypparchus, who made the first catalogue of fixed Stars, with those of a modern date, we readily perceive they do not agree; but this difference is accounted for partly from the inaccuracy of the instruments employed by the ancients, and partly from their ignorance of the laws of refraction, the aberration of light, and the nutation of the axis of the earth. Mr. Mayer, however, a celebrated mathematician and astronomer having verified those particulars, has shewn in the case of several of the fixed Stars, that they must necessarily have shifted their place, nor does he entertain a doubt that upon a general verification, it would be found, that the same thing has happened to all the fixed Stars without exception. It is the same philosopher who was prematurely carried off in the midst of his astronomical pursuits; while his merit, regarded as the patrimony of his family, was honoured and rewarded since his death by the parliament of Great Britain; a distinction so much the more creditable to his memory, that it has been conferred by a whole nation, the nation the most free and enlightened on our globe.

Other

Other trials might be made in order to ascertain whether our Sun revolves round a centre: If this centre be such as to determine the Sun to gravitate towards it, all the bodies which compose the solar system will gravitate towards it in like manner. And hence will result a double gravitation analogous to the double gravitation of the moon towards the earth, and towards the Sun; a circumstance which will give rise to irregularities similar to those which the Moon exhibits in her motion.

Thus the first question would be, whether similar anomalies have been observed, either in the annual motion of the earth, or the periodical motions of the other planets.

It is said to have been often remarked that the Sun's place ascertained by observation, differed nearly a minute from the place marked in the astronomical tables; it might be of consequence to observe if that happens in regular times, and what is the cause of it. Perhaps it would be found that a change of position in the aphelions, and in the line of the nodes of the planetary orbits, as well as the changes in the obliquity of the ecliptic, are owing, at least partly, to the double gravitation we have just mentioned. Those irregularities ought

ought to be more sensible in the higher planets by reason of the size of their orbits; but on the other hand, the slowness of their motion might prevent our observing them for a great series of years. Be this as it may, those irregularities ought to become more or less perceptible in proportion, as the solar system gravitates in a greater or less degree towards the centre of our system among the fixed Stars.

Accurate observations on the Sun's atmosphere, and the zodiacal light might furnish a new proof of the Sun's motion round a centre.

This atmosphere must be considered as a very thin light fluid, which by its gravitation towards the Sun's surface, becomes a part of himself, and accompanies him in his motion as our atmosphere accompanies the earth.

But its appearance varies according to times and seasons. It is seen to terminate in a point more than a hundred degrees from the Sun; not, however, that it actually terminates in a point; we see it in this manner as we see the edge of a lense convex on both sides, when our eye is in the same plane. It should seem, therefore, we may thence conclude, that the zodaical light is neither circular nor concen-

tric

tric with the Sun, but rather oblong or elliptic, and let us observe why:

Whatever be the figure of this curve, the line proceeding from the eye to its apparent point will be its tangent. One may imagine, then, a triangle whose three angles terminate at this point, the Sun, and the eye of the spectator. The angle formed in the eye will necessarily be an obtuse angle of 100 degrees, Consequently, the other two will be acute, the sum of which will be only 80 degrees. However small then you make the angle at the Sun, that which falls on the point of zodaical light will always be less then 80 degrees; but this would be impossible if the shape or contour of this light was circular; because, in this case, the tangent ought to form a right angle, or an angle of 90 degrees with the radius.

Geometry teaches us that the angle in the eye being obtuse, the opposite side ought to be longer than both the other sides taken together. Whence it follows, that the zodaical light, when its point is above ninety degrees from the Sun, extends beyond the Earth's distance from him. At other times this point does not recede from the Sun more than fifty

or

or sixty degrees, and then it falls within the orbit of the earth. From this it has been inferred, that the solar atmosphere is extremely variable; and the inference is just, supposing that this atmosphere is concentric with the Sun. But then it would be inconceivable, that this point should recede to the distance of 100 degrees, and pass the Earth's orbit; for, were this the case, instead of seeing the figure so accurately terminating in a point, we should see the zodaical light diffused over the face of the heavens, I mean entirely blinded with the crepusculous light.

This is the case in summer; for we never see this light distinct by itself, but from the beginning of autumn to that of spring: Nor is it difficult to conceive the cause of this, provided we give it the figure of a long elipse, whose focus is occupied by the Sun, while its perihelion is within, and its aphelion without the orbit of the Earth. In the summer months, the Earth passing near the aphelion of this light, traverses, and is, in some sort, drowned in it; and, it is for this reason, we cannot distinguish it. In the autumnal and winter months, on the contrary, the Earth passing near the perihelion of the zodaical light, is placed without it; and, consequently, it becomes visible to us in the morning during autumn, in the morning and evening during winter, and in the evening only at the beginning of spring.

In order fully to ascertain this theory, it would be necessary to pursue these observations for some years successively. We should thence more clearly perceive how far the figure of the zodaical light may be determined by tangents drawn to its point, and how far its variableness influences its apparent length, and its different phenomena. It would not be sufficient, however, to have those observations made in Europe only, because here its whole contour does not fall within the field of our view.

If it should be found in fact, that its figure is not circular but oblong, it would be extremely difficult to assign any other reason for its having this species of curve, besides the periodical motion of the Sun, and his gravitation towards the centre of the system of which he makes a part.

CHAP.

CHAP. II.

THE FIXED STARS AT DIFFERENT DISTANCES FROM THE SUN.

BEFORE we proceed in our enquiry concerning the motion of the fixed stars, we must endeavour to have a just idea of their situation and arrangement in the heavens. When we raise our eyes to the firmament, we see the whole of the stars attached, as it were, to the same vaulted surface; this, however, is an optical illusion; they are, in reality, at very different distances from us, as well as from the Sun, which is the fixed star of our system.

In order to prove this, we shall not have recourse either to the annual paralax of the Earth, which is too inconsiderable to measure such vast distances, nor to the observed motion of the fixed stars, which the observations of several centuries would scarcely be sufficient to discover, even in a small degree.

Our evidence will be derived partly from the apparent as well as real light and magnitude of those stars, and partly from the laws of cosmogony.

One

One star appears larger than another, not only because it actually is so, or that it is at a smaller distance from the eye; but, likewise, because it has a greater degree of lustre; a circumstance the reason of which we discover in the pupil of the eye, in the confusion of the image painted in the retina, and in the dispersion of the light on the same organ. Our best glasses, by extinguishing the scattered and tremulous rays, shew us the fixed stars like so many luminous points. For similar reasons, one star seems to shine with a greater brilliancy than another, especially if it has more lustre in its own nature. We may presume, also, that their light suffers a diminution in the atmospheres of the Earth and Sun, in the ether itself, in the atmosphere of other fixed stars which it traverses, and in that of the bodies which revolve round themselves. Thus the more distant a star is, the more pale and feeble will its light become by the time it reaches the eye; but, if all the stars were equally distant, their light would decay proportionally, and this difference would not exist.

If they were all of the same magnitude, and equally brilliant, we should thence infer, that such as appear of the smallest size are the most

remote

remote. And, were they all at an equal distance, we ought to conclude that the small ones had, at the same time, an inferior degree of brilliancy. It is observed that the number of stars in the different classes of magnitude increases nearly as the square of the term of each magnitude. There are eighteen of the first magnitude, sixty-eight of the second, two hundred and nine of the third, four hundred and fifty-three of the fourth, &c. It is certain that this progression is much better accounted for by the different distances of the stars, though we are far from contending that they are all equally large and equally luminous.

Neither the plan of the universe, nor the central forces, allow us to suppose that the stars are all at the same distance, and move, each accompanied by its millions of comets, in the plane of the same sphere. From this arrangement, collisions, interferences in the spheres of activity, intersections of orbits, and, in one word, disorder and the most fatal catastrophes, would inevitably ensue. Besides, this would be to limit unnecessarily the number of stars; for, it can be proved by mathematical demonstration, that round the sphere of our sun's activity, for example, there would be room for twelve similar suns only at the same distance. But what is this compared with the vast number of fixed stars which we behold, and which we can easily conceive in the regions of space. It is necessary then, in order to employ this space to the best advantage, to place them at different distances in long serieses.

We are in condition to shew that the same consequences result from the laws of gravitation. Let us take two stars whose apparent distance from each other in the telescope is only a second. If we suppose them equally distant from me, the observer, I should have an isoceles triangle, whose two sides terminating at my eye, would inclose an angle of a second, and whose shortest side opposite to this angle, would be the distance between the two stars. As the result of a trigonomical calculation, we find that one of the long sides would exceed by 206,265 times this distance; so that it would only be the 200 millionth part of their distance from me, or, what would here be the same thing, of their distance from the Sun. Consequently, if we suppose that the two stars are at an equal distance from us, the interval between them would exceed, by twice

and

and a half only, the distance of the Earth from the Sun. But at so small a distance it would be impossible that they should maintain their places. One of two things would happen; either the law of gravitation would draw them towards each other, and at last precipitate the one upon the other; or balanced by their centrifugal force, it would determine them to revolve round a common center. But then, there being so small a space between them, this motion ought to have long since been observed at least by the telescope: the same stars would have been seen sometimes going before, and sometimes following behind: every thing would be in motion in the firmament, and, above all, in the milky way, where stars appear in numbers like drops of dew upon the grass. But no such thing has been observed; and, from the days of Hypparchus to the present time, it has scarcely been possible to distinguish the smallest change of place in the fixed stars.

All this serves to prove that the fixed stars are distributed in the regions of space, at different distances, proportioned to their respective spheres of activity, and arranged in series the one behind the other.

CHAP. III.

THE MILKY WAY. THE FIGURE OF THE STARRY FIRMAMENT.

IN every other region of the skies, the stars appear to us more or less frequent, or thinly sown on a given space, but distinctly separated from one another. The milky way presents a very different appearance. The telescope has shewn us, that this luminous zone, or girdle, is a vast cluster of fixed stars, whose light, mixed and confounded, on the retina, paints in our eye nothing but a surface of one continued whiteness. This immense assemblage of stars which seem to croud and press one upon another, merits our closest attention.

The out-line of the milky way seems extremely irregular to the eye, and its breadth very unequally verging from three deg. in some places to 25 deg. in others even to 30 deg. There are places where it appears broken,

lace-

lacerated, or split into several pieces, some of which seem to overleap the general boundary. In short, taken all together, it is visibly detached from the rest of the heavens, and the number of its stars, compared with those that are without it, is like the ocean compared to a drop of water.

What then is the cause of this apparently feeble light in the stars of the milky way? For all the fixed stars being destined to serve the same end, we see no reason to believe that these have a light originally weaker than the rest. It can only be on account of their distance then, that they make a fainter impression on our senses. The milky way lies in the back ground of the other stars, at such an immense distance, as prevents our discovering its component stars otherwise than with a telescope. This being the case, no reason can possibly be assigned, why those stars should not be in themselves equally large and luminous with our Sun.

The circumstance of distance leads us to conceive, in like manner, that notwithstanding their apparent proximity, they may be separated from one another by vast intervals. And, in fact, every thing concurs to persuade us, that

that there is a distance between them similar to what exists between the other fixed stars; for example, between the Sun and Sirius, or the fixed star the most contiguous to our system. For if their object be the same with that of all other Suns, if, like them, they are destined to communicate light and heat to a million of opaque bodies, upon what authority would we abridge their spheres of activity by contracting their respective distances?

But if we suppose that those stars are separated by distances equal to those that the other fixed stars hold in respect of one another, we would thence draw this other conclusion, that the stars of the milky way are arranged not in the same line, but the one behind the other in immense serieses. Let us recur to our isoceles triangle of the preceding chapter, terminated by the line of a second, which joins two stars of the milky way, supposed to be equally distant from us, and by two lines drawn from each of those stars to the eye. We have seen that one of these last lines would exceed, by two hundred thousand times, the distance between these two stars, which, however, as a result of our hypothesis,

sis, ought to exceed by five hundred thousand times at least our distance from the Sun. Thus these two stars would be five hundred thousand times two hundred thousand, that is to say, a hundred thousand millions of times more distant from us than the Sun. But can we conceive, that at this prodigious distance they should be still visible ? It is therefore impossible that these two stars should be at the same distance from the Earth : and, consequently, it necessarily follows that the stars in the milky way are some more, some less remote, and that they succeed each other in numberless serieses, stretching progressively into the abyss of the universe. The stars which are out of the tract of the milky way, being also, as we have shewn, at various distances from us, form similar serieses, though less extended in length.

Let us consider at present the whole visible stars in mass, and we shall perceive that this whole does not exhibit a spherical figure, but rather that of a physical plane or disk, whose diameter is much greater than the axis which measures its thickness. In this plane lie the milky way, and all that is without it : it may be regarded as the ecliptic of the other fixed

 stars.

stars. It represents a flattened cylinder, or a spheroid, which for a row of a hundred stars in its thickness, ought to have a train of millions in its length; and it is this that defines the general aspect, or *coup d'œil*, for we see it in an oval form.

CHAP. IV.

THE SYSTEM OF THE FIXED STARS.

LET us apply, by way of analogy, to space, comprehending the whole universe, what we know of space occupied by the solar world; and let us endeavour to rise, by just gradations, from system to system, till we at last arrive at the universal system.

The most simple system of which we can form an idea, is a planet, such as Jupiter, Saturn, or the Earth, with moons or satellites, which revolve round it. The Sun, with all its comets and planets, primary and secondary, forms a system of greater intricacy; and to each

each fixed star is attached a similar system. In short, the sum of all the fixed stars will constitute the universal system.

But have we not been too rapid in our arrangement? Have we not made too great a leap from the second to the third gradation? Nature's progress is more slow, her advances are more gradual, and there is every appearance, that, between the second and third step of the process, there is a vast gap to be filled up by intermediate divisions.

It is natural, and in the order of things, that number, space, and time, should increase proportionally, according as the system expands. The Earth has but one satellite, Jupiter has four, Saturn five, in the proportion of their distances from the Sun and of their masses, which render the borrowed light of these satellites more or less necessary. The Sun reigns over millions of globes. But in respect of a system of Suns, millions will be but a fraction. Let us conduct our enquiry then by this principle of analogy, and pursue the footsteps of nature.

First of all, let us consider the milky way separately from the rest of the heavens, from which it visibly separates itself, and make but one

one system of all the stars that are without it, including such as cover certain points of the milky way, but which, being seen by the naked eye, are at a very considerable distance from it. In this system our Sun has his place.

But do we not perceive, in the milky way itself, certain intervals, or separations, which indicate a plurality of system? In various places we observe it as it were crushed and broken; and, in its higher altitudes, it may still contain numberless systems, which, hidden the one by the other, prevent our discovering the limits by which they are bounded.

All those systems of worlds resemble, though on a large scale, the solar system, in as much as in each, the stars of which it is composed, revolve round a common center, in the same manner as the planets and comets revolve round the Sun. It is even probable that several individual systems concur in forming more general systems, and so on. Such, for example, as are comprehended in the milky way, will make component parts of a more enlarged system; and this way will belong to other milky ways, with which it will constitute a whole.

It

If these last are invisible to us it is by reason of their immense distance. The fixed stars that are nearest to the Earth give us a certain degree of light, in as much as in a fine night, it so far subdues the darkness, as to enable us to see and distinguish the objects around us. This light, though weak, may render a still weaker light wholly imperceptible. Stars of the seventh and subsequent magnitudes escape our observation, nor do we see them even indistinctly, except when they are at once extremely numerous and crouded together; witness the *nebulæ*, seen by the telescope. Hence we may have an idea of the infinite number of stars that people the milky way, which is at such a prodigious distance from us; for it is to nothing but to the united rays of those stars that we are indebted for the impression they still make on the organ of vision.

It would not be at all astonishing then, if milky ways, situated still farther from us in the depths of the heavens, should make no impression on the eye whatever. But who knows whether the pale light that is observed in Orion, and through which Derham fancied he saw the empyreal heavens, is not one of those milky ways nearer to us than the rest? and, per-

perhaps, by a diligent application of the telescope, we may discover elsewhere similar appearances. The variations said to be observed in this, ought not to discourage us. At our vast distance from the object, it is scarce possible that, seen across our atmosphere, and optical instruments, it should uniformly display the same aspect, and be equally well defined in the bottom of the eye.

Here then is the milky way parcelled out into various systems, each of which has its center of revolution, and the whole of this way taken together, still making but a very small part of a great system in which it is included, with an infinity of others of a similar description. In short, this great system has in like manner its center, round which revolve all the systems that compose it, as well as the particular center of each of those systems. Here we merely suggest an idea, which will be unfolded afterwards, when we come to consider more particularly the nature of those motions and centers.

We now proceed to make a remark which solicits our notice. All those systems of fixed stars, that in which we are included, as well as those in the milky way, are in the same plane,

plane, which, however, is extremely extensive. But we have seen in the constitution of the solar system, that in order to promote its population, it was of consequence, that the orbits of the celestial globes should not lie in the same plane, but be inclined as much as possible, to one another under different angles. Why then is this principle applicable as it is to the economy of great as well as small systems, not equally observed in both ?

We might answer, that the firmament, as exhibited to our view, is but a small part of the whole; and that the milky way is, perhaps, to the universe, only what Jupiter or Saturn, with their satellites which are placed nearly in the same plane with their planet, are to the solar world. We might answer still farther, that as the systems of the milky way are not at rest, but in motion, we know not what aspect they may assume in time to come, and after the lapse of some myriads of ages. It would however be singular enough, should we happen to live precisely in the period when they occupy the same plane.

In the mean time let us attend to those breaks or chasms which seem to trace out

even

even to our senses the limits of visible systems.

First of all we see the milky way evidently detached from the starry heavens, which as we conceive, make a single system only where we are pent up with our Sun and his whole train. In order to represent to ourselves this separation under a sensible image, let us fill up the void which is between the milky way and the rest of the heavens, by supposing it equally replenished with stars.

Let us conceive a vast illuminated area; place upon the ground some thousands of rows of lamps at equal distances; raise above them a second tier of the same extent, and every where of the same height; in short, above this, let there be a hundred similar tiers, one over the other; and let us place ourselves in the center of the illumination. If we turn our eyes vertically up and down, we shall see fifty lamps only, but the more we incline them towards the horizon, the more the number of lamps that come under our eye will be increased; and this increase will be nearly proportionate to the secants of the angles. As we thus survey the illumination, it will appear no where interrupted; we shall no where find in it any thing analogous to that intervening chasm or void so observable between the milky way and the rest of the heavens.

But let us now withdraw one great circle of intermediate lamps, allowing those to remain that are nearest, as well as those that are farthest from us. What will be the consequence? We shall see the former both larger and more luminous; the latter fainter, and apparently more close to one another. This is precisely the effect which the illuminated heavens produce on our senses. We see the stars of the milky way blended, and, as it were, touching each other. This proves that a vast void exists between them and the rest of the heavens; if this were not the case, the interruption we speak of would not appear so sudden and abrupt; it would be gradual, and we should see the stars decrease in number by little and little, even to the milky way. We must add, that this is the only satisfactory account that can be given of the apparent extreme proximity of the fixed stars in the milky way to one another.

But there are similar chasms in the milky way itself, though, by reason of its distance they

they are not so exactly defined. If we begin by considering such of its systems only as are most contiguous to the system of fixed stars, of which we make a part, and suppose them at nearly equal distances from one another, we can scarce conceive more than six of them in the same plane; the others are in higher altitudes and at greater distances. The apparent diameter of the most contiguous systems will scarcely be equal to the mean breadth of the milky way, and will be about ten degrees. Thus, if we take for our measure their true diameter, the intervals between those systems will correspond to six such diameters. Perhaps, however, the apparent diameter, instead of ten, will not exceed five or six degrees, and thence one might conclude, that the vacant intervening space between two systems, is ten or twelve times the breadth of those systems. In short, as the milky way, in spite of those interruptions, appears upon the whole to be continuedly one and the same, there must be above its visible axis, numberless systems which cover its vacuities. The milky way, however, has its limits, and, as we have seen above, it is possible to imagine an infinity of others of which this makes but a small part.

It

It is unnecessary to inform the reader, who has followed us with attention, of the use of those large voids between the systems of fixed stars; he readily perceives that they are for the purpose of admitting orbits which require a wider scope, in proportion as the system becomes more complicated and extensive.

In considering farther the oval form of the milky way, such as it appears to us, we find its distance from the arctic to be 35 deg. and 25 only from the antarctic pole. It cuts the equator nearly into two equal parts. Whence we may infer that our system of fixed stars is not only somewhat out of the plane of the milky way, but likewise nearer its circumference than its center. It is probable enough, that the part of the milky way to which we approach the nearest, is that which cuts the colure of capricorn, in the spot where its breadth is double, where it seems as if it were divided, where the small axis appears to pass through and opposite to the constellation of Orion, from which besides it was right to remove somewhat our Sun, in order to give the series of stars ranged the one behind the other, a greater length.

With respect to the position of the milky way, relatively to others of the same description that is not easily determined, because we know nothing positively of any other but this. Hitherto we have only shewn that the pale light seen in Orion may be something of the same kind, and that more of those lucid appearances may be discovered by diligent observers.

In fine, we may also proceed eastward in our system of fixed stars. We shall at least perceive, that our Sun is not in the extremity of the system of which he makes a part. This system being separated from the rest by an immense inverval, were we placed on its confines, we should see the stars of the first magnitude in one hemisphere of the Sun only. But we see them in part every where, and consequently the Sun is nearer the center; though we must not carry him too near it neither, for reasons that shall afterwards be assigned. But at what distance, in what precise situation he is placed, we know not.

CHAP.

CHAP. V.

OBJECTION.—LIGHT OF THE FIXED STARS. AT WHAT DISTANCE IT IS PERCEPTIBLE.

THE milky way offers to our view, by reason of the distance of its stars, a tract of one continued whiteness. This confused image dissolves in the telescope which exhibits it in its whole extent, sparkling with luminous points, distinctly separated from one another. But how is it possible, that at such enormous distances as we attribute to those stars, we should be able to distinguish them? Or, that our instruments should be powerful and perfect enough to subdue all the heterogeneous light, and present them to us in the form in which we see them? This leads us to an optical discussion which is none of the most easy.

As long as we can distinguish an object with the naked eye, its lustre remains nearly the same at all distances and in all situations. Here we may disregard any variety occasioned by a greater or smaller aperture in the pupil of the eye, for which it is easy to make allowance, and consider the aperture as a permanent quantity. Thus, as long as an object is distinctly painted on the retina, we see it in its true light or brightness. If the Sun were as far from us as he is from Saturn, or even farther, that distance would in no degree diminish his lustre, though we should see him a great deal smaller.

Let us now suppose that an object withdraws from us to such a distance as that we can no longer have a distinct view of it, nor distinguish any thing on its surface: two cases will come to be considered. Either this object retains a certain extension, or it appears but like a point.

If it has a visible extension it necessarily follows, that the light emitted from its different parts will be mixed and confounded; whence results a compound or mean light composed of all these partial lights; and this mean continues always the same without regard to distance. It is for this reason that a wall on which the Sun shines, appears, whether near or at a distance, equally bright, so long as it reflects the light under the same angle; and were the Moon to approach the Earth we should see her larger, but not more luminous; it is true, that in this case, a greater quantity of light

light would fall into the eye; but it would be so much the more scattered on the retina, and by this means the excess of its quantity would be balanced and destroyed. It is for this reason also that we see equally well with a convex and concave glass.

It is quite otherwise when a confused object appears under the form of a point. In this case the rays are dispersed on the retina, and occupy a larger space than they would do, if we saw it distinctly. Two of those points that are near each other coincide, and form but one in the eye. It is this that deadens the lustre of the fixed stars; for at what distance soever they may be from us, could we view them distinctly, their lustre would strike us with the same vivacity as that of the Sun.

We endeavour to obtain this distinct vision by the means of glasses, to which, in respect of brightness, we may apply all that has been said of the eye, with this single difference, that here distinct vision depends much less on the aperture of the pupil, than on that which is given to the object-glass.

It follows that glasses do not give all the brightness to objects they would be seen in by the naked eye, were the naked eye in a situation to see them as distinctly. But, as they diminish it in a just proportion, and, what is more, without regard to distance, they are the means of supplying us with a term of comparison. If we wish to compare, for example, the different degrees of brightness in the planets, we must observe them with the telescope which brings them distinctly into view.

In consequence of this, if a fixed star whose inherent brightness equalled that of the Sun, was painted in the field of the telescope, under a figure equally well defined, that star would have the brightness or lustre of the Sun, seen by the same instrument. But the apparent diameter of the nearest fixed star scarce making the fourth of a third, we must relinquish all hope of ever seeing one of those stars so distinctly expressed; and, therefore, they will always be more extended on the retina than they would be were they seen in distinct vision.

Let us take a telescope which magnifies a hundred and twenty times; the diameter of the star instead of a fourth of a third, will appear of half a second; hitherto we have no reason to believe that we can see distinctly under

der

der so small an angle. The reason is this, that the lustre of the star, though falling on so minute a point of the retina, has, nevertheless, an equal force with the light of the Sun which falls upon the same point through a telescope; an impression of this intensity could not fail to communicate vibrations to the adjoining fibres, and consequently enlarge the image by diffusing it over a larger surface.

This hinders not that the telescope should serve to render the image more distinct, and to give us a more lively sensation of its luminous points by the approximation of its parts to the retina; and, hence it is, that the fixed stars appear smaller, and, at the same time, more brilliant, in proportion to the excellence of the instrument we employ. We have first supposed the diameter of the telescopical star of half a second; let us now suppose that the vibrations communicated to the fibres extend it to five seconds; the star will still continue smaller than it appears to the naked eye, which sees its diameter constantly under an angle of at least two seconds, and consequently twenty times larger than in the telescope. Thus is the lustre of the star diminished nearly six hundred times to the naked eye; and, if we take it at half a second, the diminution will go the length of sixty thousand times.

The difference of distance in the fixed stars in respect of brightness is imperceptible in the telescope, and in this view their distance may be conceived to be infinite; but it diminishes their apparent magnitude. Let us suppose a telescope perfect enough to subdue the parallel rays in such a manner as to concentrate them in a single point of the retina; the image of the more remote stars would, no doubt, be lessened, but without losing any degree of their lustre. The question then would be reduced to this; to determine the smallness of a point in the retina, on which a light equal to that of a fixed star by being their concentrated, would cease to produce any sensation whatever. But, how delicate and flexible soever the visual fibres may be, this point ought to be infinitely more so, in order that such a light should no longer occasion any sensible motion in the nervous mass.

Although neither our eyes nor our glasses be instruments of so exquisite a construction as to reproduce on the retina each geometrical point that they transmit, they nevertheless approximate this perfection, inasmuch as we have the advantage

advantage of adjusting the telescope to the focus of the eye. By this means we are enabled to distinguish a point whose apparent diameter in the telescope is scarcely a second. Spectacles make us see objects as if they were placed at the distance of eight, ten, twelve inches: but M. Muschenbrock is convinced by experiment, that at this distance we can discern a thread not exceeding the 1,948th part of an inch in thickness, and consequently whose apparent diameter is not even a second. There is no manner of doubt that we thus discern a spark on the point of being extinguished. Since then the distance of the fixed stars affects their apparent magnitude only without occasioning the smallest change in their lustre, we conclude, that the fixed stars might be drawn back to a distance exceeding, by some thousands of times, their actual distance, and still be visible in the telescope; for this will happen as long as they continue to excite a sensation in the eye.

Though the image of a star on the retina should be smaller than the fibre on which it falls, it will, nevertheless, make it wholly vibrate; as the idea of magnitude is attached to this vibration, all the stars seen with the

the same instrument ought to appear of the same magnitude, and merely as luminous points. But there will be a difference in their brightness, since the vibration will become gradually weaker in proportion as the distance increases. It must be weakened, however, by innumerable shades of difference before it becomes altogether insensible; for, since nocturnal darkness itself does not wholly deprive us of the sight of surrounding objects, we may hence infer what must be the sensibility and delicacy of the visual fibres; a star would still excite a sensation in this organ even were its light to become much weaker than that of a wall or bit of paper under the light of the Moon. The brightness of the Moon is near five hundred thousand times less than that of the Sun and fixed stars: the brightness of paper seen by moon-light has scarce a one hundred thousandth part of the lunar brightness; so that we might diminish by fifty thousand millions of times the brightness of a fixed star, before it ceased to be as bright as a piece of paper under the light of the Moon. To what an immense distance, then, in the heavens must not the star Sirius have dived, before he dwindled in the telescope to his present feeble light;

and,

and, hence we may judge, in proportion of the distance of the stars in the milky way.

Again, the service we derive from the telescope does not so much consist in discussing the false and heterogeneous light, which throws a confusion on the image; that would, in some sort, be an inconvenience, in as much as with it we should lose a great part of the light of the stars, while their lustre would be diminished. Its great utility arises from its collecting and concentrating their light in one point, and with a precision proportioned to the excellence of the instrument. It is this property which preserves to the point the whole of its lustre, a lustre more or less vivid in proportion as the point is more or less accurately defined on the retina. Of this the satellites of Jupiter and Saturn supply us with an example; if we do not see them with the naked eye, it is because their light is dissipated before it reaches us; but the telescope which collects their scattered rays shews us these satellites almost as clearly as their planets; nor would there be the smallest difference in this respect, if the telescope was powerful enough to exhibit them in the same distinct vision.

It

It is then extremely possible to perceive stars that may be thousands of times farther off than those of the first magnitude; and this is, no doubt, the case with the stars and systems of the milky way.

Galileo counted four hundred stars between the sword and belt of Orion, a district of ten degrees in length, and one in breadth. The heavens, considered as a spherical plane, contains 41,253 of those degrees. Thus reckoning forty stars to a degree, and supposing them every where distributed in the same proportion, we shall have in all 1,650,120 stars. If we place twelve about the Sun, four times twelve in the second order, nine times twelve in the third, and so on, making their number increase as the squares of their distances, we shall find, including the Sun, seventy-five distances or orders, before we arrive at the sum total, or the number 1,650,120. Thus we shall have, in our system, stars of the 75th magnitude, whilst the smallest that we see with the naked eye are of the 6th. Taking, therefore, for our rule of measurement, the distance of Sirius, the diameter of the system will be equal to a hundred and fifty times this distance. We have placed the system nearest

to

to us in the milky way at ten times a greater distance. The inner diameter then of the milky way will contain this measure about fifteen hundred times. As to the outer diameter, considering the vast quantity of stars which we have ranged by hundreds, the one behind the other in replenishing the milky way, it is not to be expressed by so moderate a number.

After all, however, we cannot imagine that the most remote stars in the milky way should be seen even by our best telescopes. Their extreme smallness must gradually withdraw them from our view, emitting, at last, only a very pale co-incident glimmering of light; it being highly probable besides, that their light is, in some degree, intercepted and weakened in the ether as well as in the atmosphere of other systems which it has to traverse.

CHAP.

CHAP. VI.

MOTION OF THE FIXED STARS.—ITS NATURE, ITS VELOCITY, ITS DIRECTION.—ORBITS.—UNIVERSAL MOTION.

NOW that we have given motion to the fixed stars, what are the nature and properties of this motion? Such is the subject of the following discussion.

The motion of the fixed stars is either rectilineal or curvelineal.

If it is rectilineal, it must either be convergent or divergent.

If it is convergent, all the stars will have a tendency to one another, or towards a common point of re-union. This would be the necessary effect of the centripetal force. If our Earth obeyed this force alone she would require but 64 days to fall into the Sun. The other heavenly bodies would take more or less time proportionally to their masses and distances; but sooner or later they would all arrive at the same point, and be hurled together in in one hideous ruin. A fearful spectacle where disorder and all the anarchy of Chaos would reign in triumph.

Dans le trouble et l'horreur, la nature expirante,
Jusqu' au Trone de Dieu porteroit l'epouvante.

If, on the contrary, this motion were divergent, all those bodies would recede to infinity from one another, and the world would be dissipated in the immensity of space. Every tie of connection would be dissolved: and, from that moment there would be neither union, nor harmony, nor system.

Such are the inconveniencies that would result from rectilineal motion, not to mention, that in general this species of motion is too uniform to answer the purposes of so complicated a machine as that of the world.

According to the laws of mechanics, a body upon which motion has been impressed, proceeds in the same direction until it is diverted from it by the application of a new force; hence we must have two forces, the centripetal to prevent the dispersion of the world, and the centrifugal to prevent its collapsing in one ruinous heap; and, these two forces must balance each other in equilibrio. From both results

results curvelineal motion, which sustains the heavenly bodies in their orbits and makes them travel round a centre.

The motion of the fixed stars is analogous then to that of the globes of the solar world; their orbits lie in every possible position and inclination; for this reason we see these stars distributed through the whole of surrounding space: an appearance which they would not have were their orbits in the same plane.

It is no less probable that their orbits are of every description, and that in this respect the same variety obtains as in our system; a variety which is necessary in order to augment the number of orbits and the population of the universe. Perhaps the observers of ages to come may, one day, discover what sort of elipse is described by our Sun in the system to which he belongs, and under what degree he is inclined to the plane of the milky way.

All the systems of fixed stars are separated from one another by vast intervals, some of which we perceive, that in particular which is between the milky way and the rest of the heavens. The whole of those intervals are occupied by orbits. Were we to give scope to the imagination, we might conceive here as in the solar world, hyperbolical orbits, in which fixed stars, with all their train, travel from system to system, perhaps from one milky way to another. But who will undertake to estimate those vast perambulations? Number and measure fail us, infinity and eternity absorb all our thoughts.

The velocity of motion in the fixed stars must be very unequal, and must suffer a gradual diminution in proportion as they are removed from the centre of their revolution. If, as we have already suggested, the Sun be not at the extremity, but rather towards the centre of the system in which he is placed, his motion ought to be so much the more rapid: on the other hand there will be fixed stars in the system, perhaps, of the sixth magnitude, whose motion is a great deal slower. If ever the astronomer should come to know the paralax of the Sun's orbit, he will see much farther into all those motions, and the different distances of the fixed stars will be gradually revealed. Then, one might take for his basis the portion of this orbit which is described in a certain number of centuries, and compare with it the change of place in the fixed stars; and, upon these *data*, we might found an operation, as we do in determining the orbit of a

 comet,

comet, by three observations. But what increases the difficulty here is, that we do not know where the center of our system is situated: we shall see afterwards what we may fairly conjecture on this head.

Let us endeavour, hypothetically, at least, to compute the velocity of the fixed stars.

I suppose since the days of Hypparchus, or to make use of a round number, since two thousand years, the nearest fixed star has advanced in its course a quarter of a degree, a supposition, which making allowance for inaccuracies, will agree tolerably well with the catalogue of Ptolemy. I give to this fixed star a distance from our Sun five hundred thousand times greater than that of the Earth. If we make this number express the *radius* of a circle, we shall find that the star has traversed four thousand of those *radii* in two thousand years. Consequently, the star traverses two of them annually, or a space equal to a diameter of the Earth's orbit, which making a third of that orbit, the star's velocity will be three times less than that of the Earth.

But we suppose, in this computation, that the Sun remains all the while at rest, and that the star pursues a circular motion round him;

but

but, as this is by no means the case, the motion which I have just assigned it is only relative, and will increase or diminish according as the direction of the motion is changed: for, in the same manner as the motion of the Earth shews us the planets, sometimes proceeding straight on in their courses, sometimes retrograde, and sometimes stationary; the motion of the Sun ought to exhibit the same phenomena in that of the fixed stars which revolve with him about a common centre. There will, therefore, be stars whose change of place will be imperceptible, and others where it will be more or less so. Now, in limiting the change of place the most sensible to a quarter of a degree, I must suppose myself in the most favourable circumstances for observing it, when the Sun and the fixed star move in opposite directions; and that will reduce the absolute velocity of the fixed star to the half of what I have mentioned, I mean to a sixth part of the velocity of the Earth.

Thus the gravitation of the star towards its centre of revolution becomes, in fact, very inconsiderable, when we reflect on the magnitude of the curve in which the star revolves. It must, however, greatly exceed its gravita-

 tion

tion towards the nearest star which we conceive to be our Sun. For the velocity of the planets being in the inverse ratio of the square root of their distance from the Sun, if we apply the same law to the velocity of the fixed stars five hundred thousand times farther from the Sun than we are, it will be seven hundred times less than that of the Earth; whereas it is only six times, and, consequently, it moves about a hundred and twenty times quicker, than if its centripetal force depended on our Sun. But all this, as we have observed above, is mere hypothesis, since in fact we know nothing of the change that has taken place in the position of the fixed stars from the days of Ptolemy.

In short, as the apparent change of place in the fixed stars depends on the motion of the Sun as well as on that of the fixed star itself, from thence, perhaps, we may in time derive the means of determining towards what region of the Heavens our Sun holds his course.

But what portion of time must elapse before we arrive at the knowledge of the Sun's revolution? Would a Platonic year suffice? Perhaps in the course of such a period he traverses only one sign of his zodiac; and, as to stars farther removed from the centre, or placed in the extremities of the system, what space of time would they require? What is the period of intire systems? And what the sum of that of a whole milky way? Here there is enough to make the head turn giddy. Those divisions of time are so enormous, so allied to infinity, that we may regard them as fractions of eternity.

Thus every thing revolves; the Earth round the Sun; the Sun round the centre of his system; this system round a centre in common to it with other systems; this group, this assemblage of systems round a centre which is common to it with other groups of the same kind; and where shall we have done?

CHAP. VII.

CENTRES.

EACH fixed star gravitates towards a centre, and has a motion round it; and in each system of fixed stars resides a common centre. But is this centre only a point in empty space, or is it occupied by a body? This is the first question we have to examine.

Proceeding by a rule of analogy, it should seem, that we ought to admit a central body, which, as sovereign of the system, governs all the bodies that revolve in it, and directs their motions. Such is the sun in the solar system, and such ought to be some large body in each system of fixed stars.

I do not absolutely affirm, that central motion could not exist in a system whose centre is nothing but a point in *vacuo*; because I have no doubt the bodies of which it is composed would nevertheless gravitate one towards another: thus, were the sun withdrawn from the system, the planets and comets would still continue to revolve round the common centre of gravity. By reason, however, of the vast distance

distance of the fixed stars from one another, reciprocal gravitation would be extremely impaired; and consequently, for the same reason, it would be necessary to diminish their centrifugal force to prevent its preponderance; without this, it would carry off those bodies at tangents, and dissolve the system. By that means the motion of the stars would be greatly retarded.

Moreover, the same motion instead of being simplified, would become more and more complex. The mean direction of gravity in each star, would be composed of I know not how many millions of simple and particular directions, and consequently subject to perpetual variations. In proportion, therefore, as a system is of vast extent and made for duration, the more it requires to be governed by a simple and general law. We have only to attend to the solar system, and we shall perceive the utility of a central body on which the whole depends. In virtue of this body, it rarely happens that the planets and comets disturb each other, and these extraordinary instances form but trifling exceptions. But were we to retrench the central body, the general law would be destroyed, and the exceptions alone would

would remain. Harmony, in that case, must be the result of an infinite combination, of individual and discordant impulsions; insomuch, that the more our view of the whole became comprehensive, the more we should find the system, instead of tending to simplicity, confused and perplexed.

We may add, that as the fixed stars gravitate towards one another, with their whole train of planets and comets, we should have the more reason to dread the introduction of anarchy, were they uncontrolled by any central body. It is hardly conceivable, that in the solar system so many bodies, the sum of whose masses greatly exceeds that of the sun, should move with regularity in their orbits if he were withdrawn. With how much more reason then ought we not to invest those vast systems of fixed stars with a central body, powerful enough to regulate their motions.

But, what shall we say of assemblages of systems of milky ways, taken as a whole? What disorder must not arise in the heavens, were we to vacuate particular as well as common centres? How should we imagine that millions of millions of planets, of comets, of suns, of systems of suns, of systems of systems,

tems, could peaceably pursue their courses, amidst an infinity of orbits mixed and twisted in each other, if all the centres were in empty space, if the directions of their respective gravities were varying every instant, if the governing law of their motions were nothing but a whimsical composition of an infinite number of exceptions; if, in short, there no where existed a common and preponderating gravitation, in condition to regulate the play of this immense machine, and to reduce it to uniformity?

Were we to expel the sun from the common focus of the orbits in our system, it could be necessary to diminish considerably the centrifugal force of the planets and comets, otherwise they would fly off at the tangents of their orbits, receding gradually from the centre till they at length lost themselves in the indefinite regions of space. Nor would even this precaution be sufficient. All the bodies in this system would, by slow degrees, approach Jupiter, the most powerful of the planets, and begin to sketch out new orbits around him. At first there would occur various disorders; it would be something like a state of general insurrection; at length Jupiter would assume the

the reins of government, and take possession of the centre of gravity, how distant so ever he might have been from it before. The gravity of the other bodies would no longer be in condition to displace him; for the efforts of his next neighbours would counteract each other by their opposite directions; * while the more remote would coalesce in their gravitation towards Jupiter himself. Were Jupiter to be dethroned, Saturn would have the best right to the empire. And in general it should seem, that the centre of no system whatever can long remain empty; sooner or later the most puissant body of the system would get possession of it, and the republic would be changed into a monarchy.

In fine, it is not easy to conceive the centre of a system which resides in empty space; on this supposition difficulties occur, which are not to be resolved; and why should we seek to encounter them without necessity? I can easily imagine two bodies should move in the same plane, describing constant and regular elipses, or circles, about a centre or common focus. The great axis of these elipses will be in a

* It may be objected, that these directions vary each instant, and therefore might at length coincide.

straight

straight line, and their aphelions opposed to each other: but it is necessary that those bodies should always make a straight line with their common focus, and consequently accomplish their revolutions in the same time. It is even possible to conceive three or more of those bodies in motion according to the same law. But we must regard the equality of their periods as physically impossible. And yet, if we do not adhere to it, or if we make those bodies move in different directions and planes, nothing will remain either fixed or permanent. Whence it appears, that a central body answers infinitely better the purposes of regularity, variety, and all the requisites of system.

But what is the nature of those central bodies? or what are the properties that entitle them to the post of honor in which they have been stationed by the creator?

The first of these properties is a mass of sufficient moment and importance to retain the system or systems in their dependence in due order and subordination. It is necessary that the central globe should be in condition to poize all the bodies which revolve round it, whatever position they may hold in relation to it; and that it should never be disturbed in such

such a degree as to be drawn very sensibly from the common centre of gravity. Thus it is, that the united efforts of Jupiter and Saturn are of no consequence, as opposed to the force of the sun: he resists them by the preponderating weight of his mass; and though the united masses of the planets and comets greatly exceed his own, it nevertheless enables him to make head against them all; for his deficiency in this respect, is amply compensated by the vast number of bodies that every where surround him, and whose attractions on the one side are balanced by attractions in a contrary direction*. Besides, the centre of the sun is that of the solar system, at least, I believe there is not the breadth of an inch between them. The case would be different with Jupiter, were he to usurp the supreme authority over our world; his mass would not be sufficient for his support against so many rebellious subjects. Saturn, above all, would be a very formidable vassal of his

* It is true, that the greater the number of planets and comets, the seldomer it will happen that those bodies shall find themselves on the same side relatively to the common focus. But unless we suppose, that in the first arrangement of things, this case was foreseen and provided against, in the course of a certain number of revolutions, it may and must occur.

his empire, against whom it would be necessary to oppose a great number of minor vassals, in order to preserve his balance.

As the central body of our system cannot be either a planet or a comet; the central body of a system of fixed stars cannot, for the same reason, become one of those stars, since he has enough to do to maintain his place at the centre of the system that obeys him, without carrying his pretensions higher, by aspiring to reign over a world of stars that are his equals. For this purpose we must have, if I may be allowed the expression, a more respectable and despotic mass.

A fixed star would maintain itself in the centre of a system of fixed stars only in virtue of opposite attractions of gravity in the other stars, without exerting any force or energy of its own. Thus it would be in the same situation as if it had either no native gravity at all, or at most in an evanescent and insensible degree. Here let us again observe, that no fixed star, were it even a central one, can be at rest; but must move with the system of which it is the centre, round another centre common to several systems; and that the laws of motion ought to acquire simplicity in proportion as the sys-

tem

tem becomes general and extensive. But the central star, of which we have first spoken, having no gravity in itself, neither would it have velocity, or it would have it in an infinitely small degree, because either it would not be diverted at all, or infinitely little from a straight line. Here then would arise, I do not say a very complicated species of order, but, in reality, the subversion of order; the remotest stars would have the most rapid motion, a rapidity which would gradually diminish in proportion as the stars were more contiguous to the center. Thus every consideration leads us to lodge in the centres, bodies of a force equal to the preservation of good order in their respective realms, and to carry all those realms round a central body on which each of them depends in its turn.

Let us proceed to another question. Is the central body of a system opaque or luminous in itself? We can perceive no utility in its possessing an original and underived light. Should it be for the purpose of illuminating the fixed stars? They have no want of it. Or in order to illuminate itself? This benefit it may have from the Suns that are next to it. Light seems to be intended for the use of opaque bodies

dies only; it should seem then that things ought to be so constituted, that opaque globes revolve round luminous centres, and luminous globes round opaque centres.

But what must be the enormous magnitude of those bodies which reign over whole systems, balancing globes of such vast masses, and making their attraction felt even to the extremities of their empire. The central body of the system to which we belong must have a diameter, at least, equal to the whole circumference of the solar system. If, contrary to our opinion, the fixed stars which are out of the milky way, constitute more than one system, we should be tempted to suspect that there are opaque centres in those regions of the heavens where astronomers have observed the appearance of new stars and the disappearance of others; this appearing and disappearing of stars may be nothing more than an eclipse. But much light will be thrown on the whole of this subject, when it comes to be known in what degree our Sun gravitates towards the centre of the system of fixed stars to which he belongs.

After all, the magnitude of those bodies ought not to alarm us; for, in the first place, we we have nothing to do with their bulk, but with their density or quantity of matter by which the law of gravitation is regulated. We have no idea of the density of matter that is not porous; perhaps gold, the most dense of terrestrial substances, would be found a mere spunge compared with such a central body.

Besides, nothing is either great or small in immensity: and, since on the wing of light we can traverse the vast regions of the Heavens, masses and volumes ought no longer to excite our astonishment. Beginning with the satellites, even suns are but bodies of the first magnitude, the centres of the fixed stars of the fourth, those of groups of systems or milky ways of the fifth, and so of the rest.

The sum of the milky ways taken together have, in like manner, their common centre of revolution; but how far soever we may thus extend the scale we must necessarily stop at last; and where? At the centre of centres, at the centre of creation, which I should be inclined to term the capital of the universe, in as much as thence originates motion of every kind, and there stands the great wheel in which all the rest have their indentations. From thence, in one word, the laws are issued which govern and uphold the universe, or, rather, there they resolve themselves into one law of all others the most simple.

But who would be competent to measure the space and time which all the globes, all the worlds all the worlds of worlds employ in revolving round that immense body, the Throne of Nature, and the Footstool of the Divinity? What painter, what poet, what imagination is sufficiently exalted to describe the beauty, the magnificence, the grandeur of this source of all that is beautiful, great, magnificent, and from which order and harmony flow in eternal streams through the whole bounds of the universe?

But, as those centres are bodies of such prodigious magnitude, would it be impossible to discover where they reside? Would it be impossible even to see them? Might we not, at least, discover that of the system to which our Sun belongs? Let us not despair: time, observation, the sagacity of astronomers, and diligent research may carry us much farther than we are apt to imagine.

The change of place in the fixed stars being fully ascertained, the paralax of the solar orbit would be the best mean of discovering the centre of their revolution. Here the case is the same as would be that of the inhabitants of the Moon if they could not see the Sun; for the Earth is to him in respect of his motion round the centre of fixed stars, what the Moon is to the Earth in respect of her motion round the Sun.

If we suppose, therefore, the inhabitants of the Moon are as able astronomers as ourselves, they will have two methods of discovering the Sun's place.

The first will consist in determining the elipse which the Moon would describe round the Earth if she were governed by the Earth's attraction alone, and then in finding the places of the greatest deviation from this elipse produced by the attraction of the Sun. In respect of velocity, for example, the deviation would be most sensible either after conjunction or opposition, and these places being given would shew that of the Sun.

By the other method they would deduce from a certain number of observations the true place of the planets; an operation which they would perform with the assistance of Kepler's laws, nearly in the same manner as we find the places of comets, though with somewhat more difficulty. The revolution of the Moon round

the

the Earth, and the distance of the one from the other would give them a paralax which they might employ with much more advantage than we can the annual paralax of the Earth's orbit in relation to the fixed stars. But this last would also render them the same services which we hope to derive from the paralax of the Sun's orbit.

It is by similar methods, then, that we ought to proceed in order to get acquainted with the system of fixed stars to which we belong, and to discover its centre. This may be found practicable in process of time; and we will then know our distance from that point. We have no reason to imagine that our Sun is placed at the centre; but neither does it appear that he is farther removed from it than by a few stars: so that his motion ought to be more rapid than that of stars situated at a more remote distance. All this will some day contribute to determine the place of the central mass.

But, if we suppose this body is of an enormous bulk, and illuminated besides by one or more fixed stars, it should certainly seem that we ought to perceive it in whole or in part with the help of the telescope. As we are at no prodigious distance from it, its apparent dia-

 meter

meter even to us may be very considerable; and, how weak soever its reflected light, it cannot be enfeebled in its passage to us in such a degree as to be rendered imperceptible. Enlightened by one or more Suns, this body ought to present phases analogous to those of the Moon. Perhaps it may have spots like the other globes; a circumstance which ought also to create a variety in its aspects. The diameter of the Sun is about double the diameter of the Moon's orbit; that of our central body then may, without exaggeration, be supposed to be greater than the diameter of the orbit of Saturn. Such a body, were it illuminated only in an equal degree with that planet, ought not to be invisible.

But are we sure that we perceive nothing like it? Has not that pale light in Orion which we were at first inclined to take for a milky way, a greater resemblance to the enlightened side of a central body? Derham did not view it as a luminous body, but rather as a sort of opening through which we discover something illuminated, probably, by the reflection of the empireal heavens. The appearance corresponds infinitely better to an illuminated body than to a collection of stars shining with their native lustre.

lustre. Certain variations have been observed in the visible form of this light; a circumstance which accords better with the spots and aspects of a central body than with a milky way; where such variations could not be perceived in so small an interval of time, unless we were disposed to explain them from a greater or less degree of transparency in our atmosphere at different periods.

In fine, this body would be precisely in the region of the heavens, where it should seem we ought to seek for the centre of our system. The Sun, by which it is illuminated, may appear to us but a small star; while the central body itself, which is incomparably larger, may be visible to us under a sensible diameter. The stars that are observed under the pale light of Orion, are certainly arranged in series one behind another, at different distances, otherwise they would be too much crouded. Finally it would be requisite that we observe the variations of this light but a few years, in order to determine whether from their regularity we are not warranted to infer either phases or a rotatory motion.

If we could see the centre of our system of fixed stars, it would not be impossible that we might discover also other centres; for their magnitude increases in proportion to the largeness of the system, and the largeness of the systems in proportion to their complexity. I say we might see those centres, unless the weakness of reflection, the vast length of way the light has to travel, or the superior brilliancy of the fixed stars should rob us of that spectacle. Who knows but the eye, assisted by the telescope, may at length penetrate all the way to the centres of the milky way, and why not even to the centre of the universe?

Besides, a principle of analogy should seem to require it. The central body ought to extend its influence even to the extremities of its system; and, consequently ought to appear under a sensible diameter, or at least be visible to the telescope. It is thus that the satellites see their planets, and the planets their Sun: the most distant planet still sees him under an angle of more than three minutes: the comet of 1759 sees him from the summit of its aphelion under an angle of a minute: a comet, whose aphelion is at sixty times a greater distance, sees him from the same point under the angle of a second; and this, in a good telescope, would exceed two minutes. It may be questioned whether any

comet

comet retires to so great a distance from the Sun; for a comet of this description taken at the lowest computation would require thirty-five thousand years to accomplish its revolution.

Again, the attractive force of a body decreases as the square of the sine of its apparent semi-diameter; and this semi-diameter cannot be invisible in any place to which its attractive force and its sphere of activity extend.

Our Earth belongs, by a chain of gradations, to several systems, and at last to the system of the universe: all the centres of those systems as well as the universal centre, exerts their influence over her. The whole of those centres then, ought, in respect of the Earth, to occupy a sensible space in the heavens; at least we have a right to suppose that we ought to see them with the telescope. Nothing but the inconveniencies arising from the transmission of light as detailed above, could intercept our view of them. For as to their magnitude, it is such as it would be necessary to render them visible.

Here then we have all the systems of the universe reduced to order, and enchased in one another. But what is our position amidst those systems? Where are we? As to this point we can speak indefinitely, negatively, and by approximation only.

The Earth is not at the centre of the solar system. The Sun is not at the centre of his system of fixed stars; a centre which is either in the region of Orion or Sirius. This system is neither at the centre nor in the plane of the milky way, though it seems to project over it a little; the portion of this way which it approaches the nearest, is that which passes by the colure of Capricorn, where its breadth is double. But where is the milky way itself in relation to other milky ways? Here ends all our science with the utmost stretch of our eyes and instruments.

CHAP.

CHAP. VIII.

ELIPSES CHANGED INTO CYCLOIDS.— UNIVERSAL MOTION.

HITHERTO we have proceeded on the supposition that the heavenly bodies revolve in elipses. The new point of view to which our theory leads us, will produce an intire change; and we shall see that we have reviewed a suite of hypotheses which overturn each other, in proportion as we advance in our enquiry.

The Moon, it is said, describes an elipse round the Earth. This would be true were the Earth at rest; but as she moves round the Sun, and obliges the Moon to participate in her motion, the orbit of this last cannot be an elipse, but a cycloid. The elipse of the Earth vanishes for the same reason, the moment the Sun ceases to be immoveable, and is found to describe an orbit round a new centre. Then the elipse of the Earth becomes a cycloid of the first degree, that of the Moon of the second, and

and the velocity of their motion increases in the same proportion.

But this order continues no longer than the new centre, or body of the fourth degree, reckoning from the Moon, is supposed immoveable. As soon as we give motion to it, the elipse of the sun vanishes in its turn; he then describes a cycloid of the first degree, the Earth of the second, the Moon of the third.

We easily perceive, that what is here said of the Moon, the Earth, and the Sun, applies equally to all the satellites, planets, comets, and fixed stars, without exception. There is not a heavenly body which does not partake of these motions, more or less complex; while each shares them in a degree suited to its particular circumstances.

We observe likewise, that as we pass on from centre to centre, these motions become more and more complicated; and their combinations only terminate at the universal centre, which alone is in a state of real and absolute rest. If, beginning by the Moon, we suppose that the body which occupies that centre is in the thousandth; the cycloid of the Earth will be in the nine hundred and ninety-eighth degree. There, and there alone, will be the true

true orbit of the Earth, while the velocity with which she describes it, will be her true velocity. But who is in condition to determine it, to describe the nature of her cycloid, to trace the perplexed path of our planet, and the strange bounds or skips she makes in the regions of the Heavens?

Nothing, however, is more evident. The Earth as well as all the other globes revolve, properly speaking, round the universal centre alone. With respect to the Sun, she only attends him in the same route, and as his fellow traveller, avails herself of his company, by partaking in his light and heat. She undoubtedly makes many circuitous, and, as they may appeas to us, useless trips, but which, as the law of gravitation supplies no other means of keeping two or more bodies together, are nevertheless necessary. She gravitates towards all the centres on which she depends; with the Moon towards the Sun, with the Sun towards a body of the fourth degree, with this last towards a body of the fifth, or towards the centre of the milky way, and so on of the rest. Thus, from system to system, our cycloid takes new inflections, which increase in magnitude as we advance in our career.

The

The satellites exhibit in small, every thing that happens in great: as they unquestionably move in cycloids, we easily perceive that the eliptic is not the only species of motion that obtains in the world. Our theory, however, requires motion which becomes more complicated in proportion as bodies are distant from the universal centre. By this means the elipses are transferred far from us, and confined to those bodies alone which depend immediately on the centre of centres: these communicate motion to bodies in their immediate dependence, and force them to move in cycloids of the first degree. From thence motion passing on to the utmost limits of the universe, becomes progressively more complex. It is in this manner that the wheels of the great machine mutually clinch and support each other; and it affords a fresh proof of what we have frequently had occasion to observe, that things become simple in proportion as we approach the sum of the whole.

As it is by no means probable that we shall ever come to the knowledge of the true cycloid of the Earth, we may continue, in our calculations concerning the planets and comets, to employ the elipse which is sufficient for all our present

present purposes. We may in like manner content ourselves with a cycloid of the first degree, so long as we only take an interest in the system of fixed stars in which we are placed. Twenty centuries hence, perhaps, when we may be in condition to give a just arrangement to the systems of the milky way, we shall adopt a cycloid of the second degree. From one epoch to another we shall go on approximating the truth, and enlarging our measurement in the same proportion. Our present measurement, as applied in the Copernican hypothesis, is the radius of the Earth's orbit for space, and the Sun's annual revolution for time. We are in the way of gaining another step; and presently our measurement will be the radius of the Sun's orbit, and his periodical time. The third epoch will give measurements on a still more extended scale.

There is this additional convenience, that complicated theories may easily be resolved into such as are more simple. This we actually experience in respect of the Moon's orbit, which we never consider as a cycloid but when we wish to account for anomalies occasioned by the action of the Sun: in all other cases we regard it as an elipse, and endeavour, with all the address in our power to make it cover all her irregularities; a mode of proceeding which facilitates the calculation of her motion, the elipse being a curve of a more simple and uniform description than the cycloid. We will apply the same method to the comets and planets, as soon as the periodical motion of the Sun shall have enabled us to observe the anomalies of their motion.

In astronomy the scenery is continually shifting, and the modes of language vary in proportion as this inexhaustible science makes progress in improvement, and supplies us with new theories. Ptolemy spake the language of the people: to Copernicus we are indebted for the language of astronomy; which Tycho Brahe in some measure confounded: Kepler and Newton rectified his faults, and gave to astronomical language a superior degree of elegance and perfection. The discoveries of the present and future times will introduce in this respect farther changes. All these different modes of language will, nevertheless, continue to be always intelligible; and may always be preserved in a certain degree, and within certain limitations.

The

The astronomers of the Moon may have suspected before us the periodical motion of the Sun as well as the universal motion; because that of the Moon depends on the Earth, and that of the Earth on the Sun. After having found that the Moon has a motion round the Earth, they would have occassion to remark that the Earth herself is not at rest, but has, in like manner, a motion round the Sun. They would then have discovered two periodical motions which would lead them to conjecture the third, and by and by the others. If the Moon herself had a satellite, this satellite having three periodical motions as a model, would, with still greater ease, come at the knowledge of the rest.

We may compare the universal motion to that of the waves of the sea, which succeed and impel one another. We see them rise and fall alternately, leaving a cavity between them, which vanishes the moment the uneven surface recovers its level. These elevations and depressions exhibit in their section a representation of the cycloids, which the heavenly bodies describe in the regions of space. The small waves shew us, in a single elevation and depression, a cycloid of the first degree. But,

in

in proportion as the wave swells, it becomes composed of small ones, each of which retains its own curvature, and which, nevertheless, follows the inflections of the large wave rising and falling along with it. Nature seems to be fond of this sort of undulations, since she contrives to introduce them into almost all her motions. It is in this manner a ship ploughs the plains of the ocean; the lever or wave which makes her rise and descend must be of a greater size in proportion as the vessel is of a larger volume; the shallop attached to her rises and falls repeatedly in the time the ship requires to do the same thing but once; but the sum of elevations and depressions of the shallop is equivalent to those of the ship. Thus it is that the celestial globes undulate in the ocean of space. They all make the tour of the centre; but the larger the mass of which a body is composed, the greater the resistance it opposes, and the more its undulations are simple and uniform. Their motion, therefore, is in its nature much more quiet and regular than that of the agitated waves of the sea; they are carried on, so to speak, by a constant and equable breeze, and they have no fear of a storm.

The

The cycloid of the Moon in the system of Copernicus, has but a very small inflection: one of its oscillations, which comprehends an elevation and a descent, amounts to thirty degrees of the Earth's orbit in length, and, consequently, about one-fourth of the whole; whilst the elevation and descent, taken together and considered in themselves, scarcely extend to the 365th part of this diameter *. Thus the length of the cycloid exceeds its height nearly four score and ten times.

The orbit of the Earth, if we suppose it become a cycloid of the first degree by the Sun's motion, will be one whose length exceeds its height a great deal more than in the proportion of 365 to one. In fact, we are entirely ignorant whether, since the days of Hypparchus, that is to say, two thousand years, the Sun has traversed one degree of his orbit, nor are we less in the dark as to the dimensions of those degrees †. The length of these cycloids

* Indeed, it may be computed at no more than a 386th part; since the distance of the Moon from the Earth is to the distance of the Earth from the Sun, at the utmost, as 854 to 330,000.

† But we know, that in this space of time, the Earth has made 2000 oscillations, Saturn 70, and the other planets in the same proportion. A comet, whose period should be of some ages, would not have oscillated so often.

depends on the rapidity of the Sun's course; if we suppose it two or three times greater than that of the Earth according to the Copernican system, the length of the cycloids will then be very considerably extended, whilst their curvature becomes greatly diminished.

This, however, does not appear to be universally necessary. The satellites of the two higher planets, in the system of Copernicus, describe a particular species of cycloid which cannot be compared to the undulations of the waves. As they move with a greater velocity than their planets themselves in their elipses, when they arrive between their planets and the Sun, their motion becomes retrograde, and their cycloids cross each other.

What extraordinary curves must not the heavenly bodies describe in their true motion? The mind loses itself when it endeavours to follow them. Let us try to form a conception of the orbit of one of those comets which travel in hyperbolas from world to world, I mean its true orbit in relation to all intermediate centres as well as the universal centre. All our ideas get into confusion, and we are obliged to desist from the attempt.

The question still returns: where are we? In what district of the universe does our

Earth

Earth proceed in her course? Through how many inflections does she steer in order to arrive at a succeeding one of a greater magnitude? Within what distance is she permitted to approach the centre of centres? What is the farthest limit to which she ventures to recede from it? In what point of each inflection would she be found at this moment? And what is the true velocity of her present motion? Is she actually stationary or retrograde, or spinning in the highest pitch of her velocity, which is compounded of all those velocities that the bodies of each degree to which she belongs, would have in their elipses, if the body of the immediately superior order remained immoveable! Would not this velocity be almost infinite? Or would it be tempered and controlled by the different directions of moving bodies, some of which are before, and some rather below. Were that the case, nothing could be more fantastical than the motion of the Earth and the other heavenly bodies; no rocket in an exhibition of fireworks presents motions whimsical enough to give us the smallest idea of it.

As to all those points we are, and will long remain ignorant. But this we clearly perceive, that all things are made by weight and measure, that the motions, the most capricious in appearance, are regulated by eternal laws; that centres, systems, and motions, are in a chain of subordination one to another, so as to make all act in concert for the preservation of each individual and the harmony of the whole.

CHAP. IX.

GENERAL CONCLUSION.—RECAPITULATION.

IN the progress of this work we have interspersed some reflections which we will here collect in one general point of view.

There is a difference which deserves to be remarked between the general aspect of the Earth and that of the universe. The former presents us with such apparent disorder as we cannot unravel, but by considering it in connection with the whole, where it falls easily under rule; whereas the latter carries on the face of it apparent order and regularity, and that of the simplest kind, but which becomes more and more complicated in proportion as we proceed in its investigation.

The rising and setting of the Sun, the firmament turning round us with its numberless stars in the space of twenty-four hours; can any thing be more simple or uniform? But in the progress of more minute and accurate observation, this uniformity disappears: we see the Moon going backwards; we see the planets swimming against a current which overpowers them, whilst, besides a motion common to all, they obey motions which are peculiar to themselves. This led to the system of Copernicus, who introduced a certain arrangement into the world; an arrangement, however, which is already, as you observe, become much more complex. By and by the Sun and the fixed stars begin to revolve in orbits; whole systems of fixed stars, and systems of systems get into motion; the order of the universe becomes progressively more and more complicated, till at last we come to it in the greatest possible degree of complexity, where we have just surveyed it.

Is it not truly wonderful, that, in the constitution of the universe, time and space should every where be so happily combined, that notwithstanding the infinity of wheels and springs which

which mutually depend on each other, and which are all necessary to the play of the machine, the visible order of nature should, nevertheless, every where preserve the same air of simplicity aud uniformity. But does not the purpose of this arrangement readily present itself? It can be no other than that the visible firmament should be in all its aspects, at all times, and for the inhabitants of all the spheres, a clock accommodated to all places, to all divisions of time, and to the exigences of the inhabitants of each individual globe. Such, in respect of us, are the diurnal revolution of the heavens, the diurnal and annual motions of the Sun; elsewhere the same clock which measures our hours, our days, our years, measures under different aspects, but with equal uniformity, centuries, thousands, myriads, millions of ages, the whole in due proportion to the situation, motion, and distance of the different globes. It even seems highly probable, that this amazing degree of intricate combination was indispensibly necessary in the first and primitive arrangements, in order to produce an appearance every where so simple, and from which we derive such important advantages.

On the other hand, if we could penetrate across superficial appearances, and ascend to the reality, we should find motion in the greatest degree of simplicity as we set off from the universal centre, and we should see it become more complicated in proportion as we removed from the central point. The bodies over which this centre exerts its immediate influence, revolve with a sort of majesty in their elipses, and have a motion suited to the dignity of their order. Then come the cycloids, the epicycloids, then those of the succeeding gradations. Here the astronomer will make an admirable discovery, he will have under his eye all the links of that vast chain depending on one another by virtue of a series, all the terms of which are formed from the preceding term by an invariable law.

This series, in fact, is the most simple and perfect of what they call recurrents, 1, 1, 2, 3, 5, 8, 13, &c. by deducting each term from that by which it is followed, the same series is reproduced. This leads us back to the supposition of an immoveable body which we have considered as moving in an elipse; by which means the cycloids that depend on it become more simple by one degree, the series

ries remaining the same. We might carry this operation so far as to set at rest any body whatever of a given order, or even the length of reducing its cycloid to an elipse. This is exactly what we do, when, according to the Copernican system, we consider the Sun immoveable, and the orbits of the comets and planets as elipses.

The system of Copernicus is, in fact, only a theory; but we have seen that astronomy can come at the truth only by carefully bringing under a review every possible hypothesis. This science, however, has made astonishing progress; by converting, at different periods, apparent arrangements into such as are more conformable to what actually exists, we have left behind various theories founded in appearances, and penetrated, if not fully and demonstrably, at least in the way of fair conjecture, even to the real and genuine order of things. Indeed, we may say, thanks to the science of astronomy, we know the heavens greatly better than we do the Earth, where we are still very far from being in condition to unravel the apparently chaotic disorder which reigns in the physical as well as the moral world. We shall have sooner arranged a system of fixed stars, and ascertained their motion, than re-

duced

duced the changes of the weather and the variations of the barometer to any fixed and determined rule. These last phenomena depend on too many minute causes, and too great a variety of particular circumstances, to be brought under a general principle. There is not an inequality on the surface of the globe, nor a mountain, nor a valley, nor a spring of water, &c. which may not be concerned in the production of these effects.

Upon the whole, we may draw this conclusion, that the heavens are made to endure, and the things of the earth to pass away. Nature changes in small, and is maintained and preserved in great. The vâst clock of the firmament can only develope its springs in the course of numberless epoques which succeed each other, and each in the epoque to which it is assigned. Hitherto we scarcely discern the needle which points the minutes and seconds.

Let us recapitulate and have done.—The law of gravitation extends universally over all matter. The fixed stars obeying central forces move in orbits. The milky way comprehends

prehends several systems of fixed stars; those that appear out of the tract of the milky way form but one system which is our own. The sun being of the number of fixed stars, revolves round a centre like the rest. Each system has its centre, and several systems taken together have a common centre. Assemblages of their assemblages have likewise theirs. In fine, there is a universal centre for the whole world round which all things revolve. Those centres are not void, but occupied by opaque bodies. Those bodies may borrow their light from one or more Suns, and hence become visible with phases. Perhaps the pale light seen in Orion is our centre. The real orbits of comits, planets, and suns, are not elipses, but cycloids of different degrees. The orbits of those bodies which are immediately subject to the action of the universal centre can alone be elipses.

FINIS.