The Earth and Man in the Universe

By Camille Flammarion

[M. Flammarion, President of the Astronomical Society of France and the distinguished author, popularizer of the sciences, in sending us the following able and exhaustive reply to the article of Dr. Alfred R. Wallace which appeared in THE INDEPENDENT of February 26th, writes us: "As, during my whole scientific career, I have been engaged in combating the thesis sustained by Dr. Wallace (see, among others of my numerous writings, the work entitled 'The Plurality of Inhabited Worlds'), I felt bound to prepare this refutation."—EDITOR.]

THE study recently published in THE INDEPENDENT by the learned naturalist, Wallace, on "Man's Place in the Universe," as indicated by the new astronomy, has aroused the attention of a great number of readers, as was naturally to be expected considering the legitimate renown of the author. Alfred Russsel Wallace, one of the founders of the system of transformism, has long been one of the celebrated names belonging to science. The part which he has taken in psychic discussions of late years proves the independence of his character, a rare quality everywhere. This scientist inspires all who know him with sincere veneration. He is not the sort of man to speak inconsiderately on any question, and his inductions are expected to be grounded on a serious basis. Consequently his arguments in support of the royalty of our planet have been read and discussed; and, in truth, they could hardly pass unnoticed.

I have just been studying them with the greatest care, and I will try to give here the result of this impartial and thorough examination. Whatever the nature of a discussion, it is always easy to be loyal and sincere; this is not a virtue. It is not so easy to be impartial, for it is impossible to dissociate ourselves from the knowledge and opinions we have acquired, but I may be permitted to say, with a scholar whose recent loss France deplores, Gaston Paris, that science has truth for its object, and truth alone, without any concern for the consequences, good or bad, undesirable or agreeable, which any particular truth might have in practice. The man who, from a patriotic, religious or even ethical motive, misrepresents or distorts in the slightest degree the facts which he studies or the conclusions which he draws is not worthy of a place in the great laboratory, for admission to which probity is a far more indispensable title than ability.

An examination of Mr. Wallace's plea in favor of his geocentric and anthropocentric theory has not convinced me; on the contrary, it seems to me to give a more solid basis than ever to the opposite opinion. As it is possible that this plea will be spread very widely and frequently quoted as a refutation of the opposite philosophic doctrine, I have deemed it proper to dissect, one by one, the assertions advanced, and to show clearly their lack of scientific solidity. In this examina-

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tion I will follow the order, which, for that matter, is absolutely logical, followed by the learned author in his exposition.

The introduction at once enables us to guess that the article will not be purely scientific, but to some slight degree theological also. The questions of the Christian teaching as to the Son of God, the immortality of the soul, agnosticism and materialism, make their appearance in it. We do not care to dwell on this phase of Mr. Wallace's discussion, but we thought it useful to notice it. Our examination of the author's statements will concern itself only with their astronomical correctness, their physiological interpretation and their philosophical value.

This study is presented in five sections. 1st. The Number of the Stars is Infinite. 2d. The Distribution of the Stars in Space. 3d. The Milky Way. 4th. Our Star Cluster. 5th. The Earth as Adapted for Life. Let us study successively each of these chapters.

I.—IS THE NUMBER OF THE STARS INFINITE.

The following is the reasoning of Mr. Wallace:

It has often been suggested that the stars are infinite in number and that the universe is therefore infinite in extent. But the latest investigations, telescopic as well as photographic, show that the proportion of increase in the number of the stars diminishes when the lowest magnitudes are reached. Down to the ninth magnitude the number of stars is about three times greater than that of the next higher magnitude. But after this the rate of increase diminishes largely. Moreover, if the number of stars was infinite the heavens would be full of them, and we should receive quite as much light from them as the sun gives at noonday. Therefore, the number of the stars is limited.

An entire volume might be filled with a discussion on this simple chapter. In the first place, we must take care not to confound absolute space with the universe. It seems to me that it is impossible for us not to consider absolute space as without bounds, limitless, infinite; for as soon as our imagination suggests a frontier to this space it leaps over it of its own accord. I am aware that certain philosophers, and those, too, of no slight authority, have gone so far as to deny the real existence of space; have believed, for instance, that it could be defined as that which separates two bodies, so that without bodies there would be no space. We venture to regard this definition as a pure sophism. Nothingness, a vacuum, would still be a property of space—that is to say, it would be a place in which we could suppose bodies.

We hold, then, that space is infinite. Does it therefore follow that the universe is necessarily infinite? No.

We can suppose, as Mr. Wallace does, that the universe is composed solely of the Milky Way, considered as containing all the stars, all the stellar clusters, all the nebulæ; it is a hypothesis that may be criticised, but can be supported. If such be the case, the number of the stars is not infinite.

I will even add that it is not so in any case, since we can always, at least in thought, add a star to the number existing, or ten, fifty, a hundred, a thousand. Space is infinite, but the number of the stars is not infinite.

Let us assume, then, with the author that the stellar universe formed by the Milky Way is limited, a proposition, really, which it seems to me no one has ever thought of denying.

We can concede to Mr. Wallace that the number of the stars is not infinite (the substantive and the adjective are, by the way, contradictory), but we cannot concede to him as a proved fact that the entire universe is represented by the number of stars known to man now or to be made known to him in the future. There may be a considerable number of stars eternally invisible to human eyes, either on account of the immensity of their distances or because the radiations of these stars are too feeble to make impressions on our retina.

It may be that the number of quenched suns is considerably larger than that of luminous suns.

It is not demonstrated, either, notwithstanding the researches of Halley, Olbers, William Struve, etc., that the light of the stars does not waste away with the distance.

We come now to the second proposition:

II.—THE DISTRIBUTION OF THE STARS IN SPACE.

The author first considers the motions proper to the stars, in virtue of which each star moves through immensity with different degrees of rapidity, the most rapid motion yet observed being that of a star, 1830 Croombridge, of 6½ magnitude in the constellation Ursa Major, which moves 7″ of arc per annum. (He might have noticed as higher still the motion of the star Cordalea 243, which moves 8″, 7 of arc per annum). With regard to these motions, as well as those which are verified by the spectroscope, there is nothing to be said: they are facts of observation. It is the same with the parallaxes and distances. The nearest of the stars is so remote that the distance of the earth from the sun, seen from this star, subtends an angle inferior to a second of arc (about seven-tenths). A person may form an idea of this tenuity by imagining that the letter o, as here printed, if removed a mile further, will represent an angle of about a tenth of a second. It is in this order of apparent magnitude that the motions of perspective of the stars in the heavens are presented to us, motions caused by the annual displacement of the earth round the sun.

It is not the brilliancy of the stars that indicates their distances. The brightest are not the nearest. It is the motions proper to them which give the best indication, the quickest denoting the stars that are nearest, just as it is possible from a hill on the seashore to conjecture the distance of the boats from their apparent displacements, in spite of the real differences in speed. It is after calculations such as these that the author starts on his investigation of the form and structure of the universe.

III.—THE MILKY WAY.

One of the most remarkable and characteristic aspects of the starry heavens is undoubtedly that nebular ring which has in all ages attracted the attention of the thoughtful. This great circle divides the heavens into two hemispheres, making an angle of about 63° with the ecliptic, so that it does not pass very far from either the North or South pole. Its appearance is known to be the result of the massing together of millions of stars, the number of which increases according as the power of the telescope increases.

But besides these minute stars which give us this milky belt, the stars of all degrees of brilliancy are more numerous in the Milky Way and in its neighborhood than elsewhere. The two poles of the Milky Way are the regions where there are the fewest stars. Observations made by certain astronomers show a gradual increase from these poles up to the borders of the Milky Way. Sir John Herschel gives the average number of stars in a square of 15′ at each 15° from the pole of the Galaxy as 4, 5, 8, 13, 24, 53.

The observations made since the enumeration of Sir John Herschel con-

firm this rate of increase. The map drawn by Proctor in the great atlas of Argelander, containing the 324,198 stars of this atlas to the tenth magnitude exclusively, a map which I published twenty years ago in my "Astronomie Populaire," shows clearly this rate of increase. The maps of Schiaparelli and the labors of Newcomb lead to the same result.

From these facts Mr. Wallace, with many other astronomers besides, comes to the conclusion that the Milky Way is a vast annular agglomeration of stars, and that we are situated toward the center of this agglomeration. Sir John Herschel, who made a thorough study of the Milky Way at the Cape of Good Hope as well as in England, thought the southern portion was nearer to us than the northern, because of its greater brightness, which conveys the idea of greater proximity. But this may be an illusion, for the Milky Way is quite irregular, and the parts near the North Pole, as well as those near the South Pole, are narrow in comparison with the parts situated at 9°. William Struve arrived at an altogether opposite conclusion. The fact that most strongly impresses the author is that the Milky Way forms a great circle, making, as we have said, an angle of 63° with the ecliptic, cutting that circle in R. A. 6 h. 47 m., and 18 h. 47 m., while its poles are in R. A. 12 h. 47 m., N. Decl. 27°, and R. A. 0 h. 47 m., S. Decl. 27°; and so we must be situated at or very near the central point in the plane of the ring. No astronomer, he adds, has been struck by the extraordinary nature of this fact, a fact which leads him to conclude that there is "some casual connection between out system and the Galaxy."

Mr. Wallace is not, as he imagines, the first to be struck by this fact. Kepler, Kant and Lambert held a somewhat similar opinion.

We purpose shortly giving our most serious attention to the aspects of the Milky Way. But, before doing so, it is proper to give a summary of a section of the English naturalist's article, as we have done in the case of the preceding sections.

IV.—OUR STAR CLUSTER.

The stars whose distance is known—that is to say, the nearest ones—are spread out in all directions, as has been shown by the investigations of Professor Kapteyn, of Groningen. This fact would indicate that those nearer stars spread round us in all directions constitute a globular mass nearly concentric with the Milky Way, and that our sun is a star of this cluster.

This was the belief, as we have already stated, of the philosopher Lambert, in the eighteenth century.

Mr. Wallace has been struck with the demonstration of Professor Kapteyn, which he accepts as certain, strengthened as it is by the arguments of Mr. Newcomb on the proper motion of the stars. The New Astronomy proves, he tells us,

"that our sun is one of the orbs of a central star cluster, and that this star cluster occupies a nearly central position in the exact plane of the Milky Way. *Therefore, we are in the center of the whole universe.*"

Such is the astronomical conclusion of the author. The last point in his series of arguments is that not only our solar system is in the center of the universe, but that our planet is the only one adapted for life in this system. We shall deal with this special view further on. The important point here is to show that the chain of argument which precedes it is very far from being demonstrated. The question, as may be guessed, is to make as exact a calculation as possible of the structure of the Milky Way, and this we purpose doing.

THE MILKY WAY AND THE UNIVERSE.

The first real astronomical investigations on the extent of the distribution of the Milky Way are due to the genius and perseverance of the great observer, William Herschel. Begun in 1784 and continued up to his death in 1822, his publications on this important subject, inserted in the *Philosophical Transactions* of the London Royal Society, exhibit considerable changes of view, resulting from the progress of his discoveries, which have not been always noticed and which so completely modified his primitive hypotheses as to upset them entirely.

At first, in 1784, the illustrious astronomer concluded that the stars were

of equal dimensions and equally distant from one another. In this conception the number of stars which could be counted in a telescopic field would correspond to the elongation of the visual ray. Herschel had just constructed a telescope with an aperture of 18.8 inches, magnifying 157 times, the field of which measured 15 minutes in diameter; this field shows an 833,000th of the entire celestial vault, and more than a million would be needed to cover the extent of the heavens. It is what Sir William Herschel called "gauging of the heavens, star-gauges." He constructed 3,400 between + 49° and — 30° of declination. The number of stars inscribed in these gauges is extremely varied, from one star, or even none, to 588 as mean of maxima. He deduced from them, as to the distance of a star of the first magnitude, 46 for the minima and 497 for the maxima.

It is conceivable that if the gauges were taken in every direction it would be possible to shape in this manner the exterior form of the visible starry universe, but as the circumpolar zones, whether northern or southern, are missing from the work accomplished, Herschel contents himself with a section of the Milky Way, and concludes from it that "our nebula is a very extended and rarefied mass which is composed of several millions of stars." The stars on the border of this stratum are in the constellation of the Eagle, 480 millions of times the distance of the sun from the earth, a space which light traverses in 7570 years, and in the Unicorn, 817 millions from the first unit, or 12,920 years of light. While engaged in this labor Herschel discovered a great number of nebulæ which he considers to be remote exterior milky ways.

A figure published in the *Transactions* of 1784 shows our agglomeration of stars under the aspect of a rectangular stratum or layer, opening in two leaves, and supposes that the projection of this stratum on the background of the heavens produces the appearance of the Milky Way. This was the theory of Thomas Wright ("The Theory of the Universe," London, 1750), upon which Kant based his own theory.

The great observer soon abandoned this first idea, already grown somewhat effete. The following year, in 1789, he presented a second Memoir, in which he discussed some new gauges, and showed our stellar universe under the form of an oblong couch, flat, elongated beyond the center, bifurcated, whose projection on the heavens would equally give birth to the apparent image of the Milky Way.

Astronomers then stopped at the very simple idea—too simple, in fact—that the stars are equal to one another and distributed at equal distances. There is no sufficient reason for admitting this equality. Our planetary system offers us a proof of the very opposite. But one of the qualities of Herschel was a disinclination to hold on obstinately to a preconceived opinion; another, to work on incessantly for his own pleasure and with the most complete independence of mind.

Altho we are obliged to make here a sort of general and comparative review of the labors undertaken for the solution of the great problem of the general constitution of the universe, we must not pass over in silence the hypothesis published by Mädler in 1846 on "The Central Sun of the Universe," which he places among the Pleiades, and which he identifies with Alcyone. This hypothesis was principally founded on the direction and on the extent of the "proper motions." The period of the sun's revolution round this point was fixed at 18 millions of years, and its velocity at about 50 kilometers a second.

In his studies on stellar astronomy, published in 1847, William Struve presents the following deductions:

"The Milky Way is not quite a great circle of the heavens, for, in taking its main track, it approaches a parallel circle distant about 92° from its Northern Pole situated on the borders of Berenice's Hair and the Dog-stars by 12 h. 38 m. Right Ascension and 31° 5 Declination. Our sun is a little distant from the center, toward the constellation of Virgo, in relation to the line of greater concentration. If we regard all the stars as forming a great system, that of the Milky Way, we have, notwithstanding, no idea as to its real extent."

In the same work, after a mathematical discussion of the stellar densities resulting from the zones of Bessel and Argelander, the learned Russian astronomer concluded that "the most

condensed layer of stars does not form a perfect plane, but rather a broken plane, or turns in two planes inclined to each other at an angle of about 10°, and having their intersection very nearly in the plane of the celestial equator, the sun being at a little distance from this line of intersection, toward the point 13 on the equator.

We must not forget in this connection the labors of Sir John Herschel in the Southern Hemisphere, published in 1847, in his magnificent work containing his observations at the Cape, but really accomplished between 1834 and 1838, in which he applied in these regions, until then very little studied, the system of gauges of his illustrious father. In the concluding inference which he draws as to the form of the Milky Way, he compares it to a ring with the sun a little eccentric in this ring, and nearer south than north. This stellar ring would be formed of a considerable number of clusters. In this appreciation, if we could see the Milky Way from the outside and in front, it would doubtless present an aspect analogous to that of the annular nebula in Lyra. The solar system would be found relatively isolated in an immense void.

These observations, researches and discussions on the grand problem of the structure of the sidereal universe are gradually shedding some light on the question, but they do not solve it, for the subject is as vast as it is complex, particularly on account of the absence of uniformity in the degree of brightness and the rents in the immense celestial girdle. There are even empty spaces, gaps, through which it seems as if one could penetrate to the very background of the heavens. Prof. Alexander Stephen, an American, has attempted to represent these varieties by the conception of a spiral nebula analogous to that of Virgo (Messier 99).* But, however ingenious this scheme may be, it is not convincing.

One of the most laborious attempts at trying to explain the aspects of the Milky Way is that of the English astronomer Proctor. He supposes that it has the form of a serpent, lying extended in oval shape, with the two extremities drawn back toward the center, leaving an empty space between them. This void would correspond to the black hole or "coal sack" of the Southern Hemisphere, and the double branch from Cygnus to Scorpio, as well as the smaller doubling of the southern circuit, would be produced by the projection of the two extremities of the serpent, winding in our direction with one part, and projecting itself with the other toward the background of the heavens.* This effort at explanation is certainly most original. But it is scarcely probable that one of the branches of the Milky Way is much nearer to us than the other. At least such is not the impression which its appearance produces on our eyes.

Here, as in all sciences, observation must be the fundamental basis of every hypothesis. Therefore, we should examine carefully the direct studies made, whether by the naked eye or with the aid of instruments, on the aspects of the Milky Way. The first map in which the Milky Way is figured with precision and fidelity to nature is that of Lubbock.† The first special atlas on this point is that of the Belgian astronomer Hauzeau, one of the most learned and modest of astronomers and at the same time one of the most eminent scholars of the last century. In his "Uranométrie Générale," published in 1878,‡ a worthy successor of that of Argelander, he comments upon the observations made by him at Jamaica, on the equator, of the two celestial hemispheres, between January 28th, 1875, and February, 1876. These observations were made with the naked eye, tho sometimes verified with the aid of a spy glass. One of the great merits of this work is the representation of the Milky Way by plates of equal lightness or isophotic lines like those made for hypsometric maps for measuring hights on the earth's surface. Instead of a continuous and uniform plan, we have here the real aspect of the different intensities and tones already described by Sir William Herschel with great care.

An examination of these maps leads to the conclusion that the statistics, from

* *Astronomical Journal*, Vol. II, 1852.

* Monthly Notices of the Royal Astronomical Society, 1869. The Universe of Stars, 1874. Old and New Astronomy, 1892.

† "The Stars in Six Maps," London, 1836.

‡ "Annales de l'Observatoire de Bruxelles," Nouvelle sérié, tome I.

all quarters, of this plane by zones give simply mean numbers which do not correspond to the real distribution of the stars in space.

The same impression is produced by the careful representation of the Milky Way, due to the scrupulously exact labor of the observer Boeddiker, at the observatory of Lord Rosse, in Ireland.* The delicate contours, the limits scarcely visible to the eye, the lightest tones, are represented by lithography, and we feel that we are in presence of a stellar immensity that is extremely complicated. It seems to me, however, that the separation extending from Alpha Cygni to Scorpio is less apparent than it is in reality. This work was achieved by the naked eye.

In a well considered analysis of the southern regions of the Milky Way, made for the preparation of the charts of the *Uranometria Argentina,* Mr. Gould showed a tendency to conclude that there are two, or even several, Milky Ways superimposed on each other.†

We have already referred to Argelander's general chart of the zones, in which Proctor set down the 324,198 stars of that great atlas stretching from the North Pole to 2° south of the equator. These observations do not reach the tenth magnitude, and stop at 9½. We see by this chart that the Milky Way projects much less than seems to the naked eye. This effect is due to the fact that we perceive with the naked eye stars of the sixth magnitude, and that all the stars of the seventh, eighth and ninth magnitudes are invisible to us, while in the Milky Way their closer agglomeration influences our retina. These stars of Argelander, moreover, do not suffice for the production of lacteal light, and there are joined to them stars still more feeble, of the tenth magnitude and even below it. We may remark also that the agglomeration does not correspond exactly to the Milky Way, it extends eastward to Cancer, and a sort of concentric zone at the terrestrial pole is sufficiently marked, distorting it beyond Ursa Major.

Mr. Easton has constructed an isophotic chart of the Milky Way, even more minute than that of Hauzeau, in which the intensities are represented by six tints that are gradual and determined by photography. The result of this representation shows that there are accumulations of stars having a certain coherence in relation to one another; they are not scattered through space and are very remote from us, proving that this is not an annular system, but a series of strata of stars more or less irregularly condensed. The greatest accumulation is found in Cygnus, in the two branches that are at different distances, which does not exclude the possibility that isolated groups are projected on the branches, which may be composed of a series of clusters more or less intimately connected. There might be in the neighborhood of γ Cygni an enormous stellar agglomeration—a center of streams of clusters, of which the most important approaches the sun in Cepheus, then bends back on Cassiopeia, retiring further and further in order to form the branch of Aquila and surround us with the southern hemisphere.

I have thought it indispensable to compare all these labors in order to acquire as thorough a knowledge as possible of the structure of the visible universe. But it does not seem to me that direct observation is still the best means of instruction here, or that the attentive examination of the Milky Way on a dark summer night gives us the best impression of reality. Enlightened by the preceding discussions, we distinguish in this vast celestial belt agglomerations very different in stellar entity as well as in extent, and we feel that, far from being a regular system, comparable, for example, to the solar system or to the systems of different orders imagined by Lambert, the Milky Way is an image of perspective formed by the superimposition of an innumerable multitude of stellar clusters, disseminated at immense distances in a principal plane. Seen *from a very great distance* our stellar universe would perhaps present in front the aspect of a disk, more or less regular, and, seen in its plane, the aspect of a rather thin line.

This conclusion is strengthened by the fact that almost all the clusters of stars, instead of being seen in all directions, are

* "The Milky Way from the North Pole to 10° of South Declination," London, 1892, 4 maps.
† "Uranometria Argentina," p. 383.

found precisely in the plane of the Milky Way.

It is extremely remarkable that the clusters of stars should be exactly accumulated in the plane of the Milky Way, while the nebulæ seem to fly from this plane and accumulate in a perpendicular sense; the more stars the more stellar clusters. On the contrary, the fewer stars the more nebulæ. Sir William Herschel had already noticed this. When in his gauges of the heavens the number of the stars became rare, he said to his sister, his secretary: "Prepare to write, the nebulæ are coming."

William Struve had already described, only, however, after the investigations of Sir William Herschel had been made, the predominance of certain clusters of stars in the Milky Way, and the absence in an opposite direction of the nebulæ. "Collecting," says he, "the clusters of stars discovered by Herschel, and considering the clusters near the Milky Way as belonging to it, we have the total number of 263 clusters, of which 225 are in the Milky Way and 38 outside. Supposing it to have a mean breadth of 10°, it takes up in its total visible extent a twelfth of the celestial vault and a ninth of the part of the firmament visible to Herschel. We learn, then, from this that the Milky Way is four times richer in clusters of stars than the other part of the heavens. We must therefore regard it as an immense collection of clusters of stars very irregularly condensed. But it is at the same time poor in irresolvable nebulæ, and it is precisely in the regions bordering on one of the poles of this circle in the constellations of Virgo and Berenice's Comæ where the nebulæ are found in greatest abundance. This remarkable circumstance appears to me to speak directly in favor of the heterogeneity of the clusters of stars and of the nebulæ."

William Herschel's catalogs contain about two thousand nebulæ. In 1864 Sir John Herschel published his general catalog, increased by the discoveries made by himself in the Southern Hemisphere; it contained 5,079 nebulæ. In 1888 we had the catalog of Dreyer, containing 7,840.* The distribution of the nebulæ in space was studied and discussed by Cleveland,* then by Proctor in 1869, and displayed on special charts. These representations of Proctor are numerous in his works and very instructive. One of the best of them (the northern Milky Way, however, leaves much to be desired) is the double map on which Sidney Waters has mounted this distribution of the clusters of stars and of the nebulæ so remarkably opposed to each other. The system of the Milky Way and the clusters of stars form the same *ensemble.*

The photographs of Barnard, taken at the Lick and Yerkes observatories, those of Wolf at Heidelberg, the researches of Newcomb on the number and light of the stars, might be examined here as documents complementary to the general facts which have just been expounded; but we have to limit ourselves to what is essential, and what has been now set forth is sufficient, I fancy, to permit us to fix our ideas on the structure of the visible universe; at least it corresponds provisionally to the present state of our knowledge.

The following are the deductions which seem to us to be the best founded:

We must consider the *stars,* the *clusters* and *the Milky Way* as forming an immense and very heterogeneous general agglomeration.

The form of this stellar universe is unknown to us. We can, however, assimilate it to a flattened, irregular sphere in which the Milky Way would mark the equator. The equatorial diameter is much greater than the polar diameter. The clusters of stars and the stars themselves are disseminated chiefly in the equatorial plane and in the planes bordering on it.

This is not the case with the irresolvable or gaseous nebulæ; the latter appear in both parts of the Milky Way at a distance from these two poles and in the circumpolar regions.

We must therefore conclude with several astronomers that they do not form part of our sidereal universe and admit the coexistence of two distinct principles, a nebulous principle and a sidereal principle. Are we, then, to believe that the nebulæ are exterior and foreign to our stellar group?

* *"Etudes d'Astronomie Stellaire,"* p. 40 and note 57.

* "Monthly Notices," 1867.
† "Monthly Notices," 1869.

This conclusion does not seem to me to be well founded, for the nebulæ show themselves on both sides of the plane of the Milky Way and become condensed, almost symmetrically, in the vicinity of their poles, contrary to the density of the stars. This remarkable distribution is not accidental.

These facts seem to show that the forces which preside over the general evolution of this universe had worked with more intensity and more activity in the equatorial zone than in the remoter zones, which were in a sense belated, colder, and, if I may say so, asleep. Will these nebulæ ever become stars? We are at liberty to think so, not only because the transformation of the nebulæ into suns and into systems explains well enough the genesis of the universe, but also because we see nebulous matter associated with the star clusters and with their evolution in the Pleiades, in the nebula of Orion and in other examples.

Besides, the fine discoveries of Mr. Barnard show that nebulous matter is still very much scattered through the sidereal universe.

In this *ensemble* our sun has not any preponderating situation. It is not more in the center than its sidereal neighbor, Alpha Centauri, or than our other neighbor, 61 Cygni, or than most of the stars whose parallax has been determined. To claim that we are the center goal of the universe is pretty much the same sort of reasoning a person residing at No. 172 Rue Rivoli, Paris, might indulge in if he imagined he was the center of Paris and the object for whom this capital was constructed.

Nay, more. While showing, according to our perspective, a structure of the visible universe, the Milky Way does not, however, represent an absolute plane comprehending our sun, for some very important stars shine, not on the central zone, but on the borders.

Let us now consider the thirty most brilliant stars in the heavens with their photometric value (Aldebaran being taken as the unit).

Sirius (1.4).
Canopus (0.8).
Capella (0.1).
Arcturus (0.2).
Vega (0.2).
Alpha Centauri (0.2).
Rigel (0.3).
Achernar (0.4).
Procyon (0.5).
Beta Centauri (0.7).
Betelguese (0.9) variable.
Altair (0.9).
Alpha Crucis (Southern cross) (0.9).
Aldebaran (1.0).
Spica (1.1).
Antares (1.2).
Pollux (1.2).
Regulus (1.3).
Fomalhaut (1.3).
Deneb (1.4).
Epsilon Canis Majoris (1.5).
Beta Crucis (1.6).
Gamma Orionis (1.7).
Beta Tauri (1.8).
Epsilon Orionis (1.8).
Alpha Gruis (1.9)
Castor (1.9).
Alpha Persei (1.9).
Zeta Orionis (1.9).
Delta Canis Majoris (1.9).

These thirty stars may be considered as the most important of those with which we are acquainted, in all cases as the most luminous intrinsically, for their brightness does not depend on their nearness. Several of them, like Rigel, Antares, Deneb, etc., do not offer any sensible parallax. Now it is remarkable that if five among them (Alpha and Beta Centauri, Alpha Crucis, Deneb and Alpha Persei) shine fully on the Milky Way, eight others shine just on the borders: Sirius, Capella, Altair, Antares, Beta Crucis, Epsilon and Delta Canis Majoris, as well as Beta Tauri. Of the seventeen remaining several are not very remote, such as Procyon on the west, Betelguese and Aldebaran on the east, or Vega, which is nearer still, or Canopus, or even Castor and Pollux, as well as the stars of Orion. All these suns are contiguous to the Milky Way. The only ones separated from it are Arcturus, Achernar, Spica, Regulus, Fomalhaut and Alpha Gruis.

Thus the brilliant stars form equally a part of the general system of the Milky Way, but our sun does not occupy a preponderating position. All the stars which we have just named may besides be considered as more important than our sun, for at their distances (except Alpha Centauri) this luminary would be a star of the second, third, fourth, fifth or sixth magnitude, or even of a still lower one.

The thesis of Mr. Wallace, then, is devoid of all astronomical foundation. The Milky Way does not form a regular system. It is an agglomeration of clouds of stars. In this agglomeration our sun is neither preponderating nor central. This theory would be perhaps excusable in an inhabitant of the system of Sirius on account of the importance of this sun. It is not so in the case of a native of our modest hamlet.

In order to try to form an idea of the number of the stars in our universe—without preoccupying our mind with infinite space and other possible universes—we may pursue the following chain of reasoning in company with Lord Kelvin.* Let us suppose a sphere with a radius of $3{\cdot}09.10^{16}$ kilometers (that is, the distance at which a star would have a parallax of 0″001) containing, uniformly distributed, a quantity of matter equal to a thousand million times the mass of the sun, the speed acquired by a body placed originally at rest on the surface of this sphere would be about 20 kilometers a second at the end of five millions of years, and 108 kilometers a second at the end of twenty-five million years, admitting that the acceleration remains constant during so long a space of time. Now these numbers are of the order of the velocities measured in the motions of the stars. If, instead of a thousand millions of suns in this sphere, we should suppose ten thousand millions, the velocities that would result would be much greater than those observed, so that we may regard the first supposition as coming near reality.

Admitting this milliard (1,000,000,000) of stars, and noting that this number appears to be a maximum in relation to the indications of telescopic and even photographic observation, in spite of the white plates of exposures of long duration; admitting it, we repeat, on account of its harmony with the "proper motions," would it prove that this milliard exists alone in the infinite, and that, for example, there is not a second milliard at a million times the preceding parallax, and a third, and a fourth, and a hundred thousand millions of universes, analogous or otherwise? By no manner of means.

It seems even that we were already acquainted with stars that do not belong to our sidereal universe. I shall quote, for example, with Newcomb the star known as 1830 in Groombridge's catalog, the most rapid of those whose motions have been determined. This motion is estimated at 320,000 meters a second, and the attractive force of our whole universe cannot have determined this rapidity, unless we suppose communications of energy due to the passages of the star in the immediate neighborhood of considerable masses. There is every probability that this star comes from beyond our universe and traverses it as a projectile.

As much might be said of the star 9352 in Lacaille's catalog, of Arcturus and Mu Cassiopeiæ. Let us take note, by the way, that the star Arcturus is at least eight thousand times as large as our sun.

At present the proper motions are not sufficient to explain either the apparent aspect of the starry heavens or the preponderance of the Milky Way. Certain stars very distant from one another have a common proper motion. The stellar systems which I discovered long ago* give evident proof of these associations. Our sidereal grouping does not form a system.

Thus, then, the supposition that our sun is in the center of the sidereal universe is an error. The supposition that it is the preponderating star is another error. The still queerer idea supported and sustained by Mr. Wallace, that the sole function of this central sun consists in giving light to our little planet and securing life on its surface, is still more untenable, as is also that which claims that the conditions of life belong to the earth alone. It is astonishing to see this great naturalist, whose theories on evolution demand the action of time as the principal factor in the succession of terrestrial species, forget here to apply the same principle to Jupiter, the world of the future in our system. By what right does he suppose, on the other hand, that the limits of our knowledge represent the limits of the potency of nature? We have every day proofs of the contrary. The long explanation required by the

* "On the Clustering of Gravitatorial Matter in Any Part of the Universe." *The Observatory*, November. 1901.

* "Comptes-rendus de l'Académie des Sciences," 1877.

preceding astronomical study precludes me from entering into any discussion here on the conditions of life and showing that terrestrial chemistry does not necessarily include the vital universal cycle. This discussion is, moreover, rendered useless by the overturning of the edifice. Since the thesis defended is incorrect, its pretended consequences are null.

We are compelled, then, to acknowledge that our planet has no marked preponderance in our system, that our sun does not occupy any preponderating place in the agglomeration of millions and millions of suns which constitute our sidereal universe, that this sidereal universe, whatever may be its immensity, is only a point in the bosom of the limitless infinite, that there is not any reason why millions of other universes should not exist even vaster and more marvelous than that with which we are acquainted, and that all our conceptions on life, on nature, on space, on eternity are impalpable impressions, motes floating in a sunbeam. We live in the relative and in the unknown, and we see that the gossamer web of our existence melts away into the bosom of an ABSOLUTE WITHOUT LIMITS, WITHOUT BEGINNING and WITHOUT END. The material world is everywhere stationed at the threshold of the heavens.

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