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THE SPIRIT OF SEEKING

~~RELIGION AND THE SCIENTIFIC METHOD~~

It would probably be possible to compile a statement outlining the Scientific Method which would be acceptable to the great majority of men of science, but when it comes to the question of the applicability of this method to the investigation of spiritual truth in general, and the scientific attitude of mind towards religion in particular, no two people - if they think at all - will think exactly the same about it. Such an attempt as that which follows, will therefore completely satisfy no one - not even the writer - but it may have its value nevertheless. It will lead to criticism; and constructive criticism, when honestly given and tolerantly received, is twice blest, "it blesseth him who gives and him who takes".

This is an attempt to bring together many desultary thoughts, gleaned at one time or another during the last few years from the writings or from the utterances of some outstanding thinkers - men of science, philosophers, poets, theologians- as well as from the somewhat chaotic abyss of my own mind.

I.

Let us consider, first, the necessary attitude of mind for the worthy searcher after truth whether it be truth regarding the world of nature around us or regarding the intangible things of the spirit. In either case these must be sincerity of purpose, extreme honesty of mind, and great courage. Perhaps the last should have been placed first - Robert Louis Stevenson has stated that "courage is the principal virtue for all others presuppose it". It often takes courage, determination, and honesty to face facts squarely and not to distort them into evidence for some preconceived theory which they do not truly uphold. Without bias and without prejudice, as far as is humanly possible, the real significance of things must be sought.

"Once upon a time", wrote Jacobi, "there were one thousand years of night". This was the period following the publication of Ptolemy's compendium of Greek knowledge of the world of nature, the Almagest, when in Europe it was regarded as the height of folly, of impropriety, and of impiety to venture to question the truth of the pronouncements of Aristotle. Every statement must be accepted unquestioningly and the minds of men were bound as with shackles of steel. The Almagest carried all the weight of authority in physical

matters that the Bible and the doctrines of the first dozen centuries of the Christian era carried in spiritual matters. Thomas Aquinas had so interwoven the one with the other that to doubt the one was to dishonour the other. Now according to Professor Hocking of Harvard University, Bruno Giordano typifies for us the new spirit, the scientific mind, which emerged in the 16th century and burst the chains of spiritual despotism, setting free the minds of men to search for truth without let or hindrance. Bruno was born in Italy five years after the death of Copernicus and the publication of his heliocentric theory in 1543. Revolting against the spiritual and intellectual tyranny of the times, he left the Dominican monastery at Naples and travelled to centres of learning in Switzerland, France, England, Germany, "determined to see for himself the noble Universe unclouded by the mists of authoritative philosophy and church tradition". The highest function of man he considered to be the contemplation of divine unity discoverable under the manifold phenomena of nature. Bruno had grasped the meaning of the paradox enunciated by Christ - "He that would save his life must lose it". Bruno realized that he who would fill his mind with the truth must first empty it of all cant, pretence, prejudice, and unthinking allegiance to dogmatic tradition. In 1600 Bruno was burned at the Inquisitors' stake and forty-two years later there died another brave independent thinker, narrowly avoiding a similar martyrdom, Galileo, who like Bruno deserves to be described in the words of Thomas Huxley as a man "filled with the divine afflatus of the Truth Seeker". Theirs was the spirit that must be ours, too, if we would likewise follow the pursuit of Truth.

II.

The Scientific Method, as a certain mode of procedure is

commonly called, may be briefly summarized under five headings. First there is observation of natural phenomena and the collection and arrangement of facts - all the relevant facts possible, not just those which fit in with some preconceived ideas. Then there is the performance of simple or elaborate experiments with a view to increasing the number and variety of facts to be added to the collection. The formulation of a tentative hypothesis follows. This hypothesis is not an end in itself - it is a means to an end that can never be fully achieved - the full and complete knowledge of the Universe can never be attained; but that mankind may approach gradually closer and closer to this ideal is the firm conviction of every man of science. We believe that the fluctuating, wavy curve of knowledge does ultimately run asymptotic to the straight line of Truth. Sir Joseph Thompson, esteemed doyen of British men of science, once made this memorable remark to a class of students at Cambridge - and let us hope he impressed it upon every class that has passed before him - "A theory is a tool, not a creed". A tool is never an end in itself, it is valuable only in so far as it assists in the production of something finer. So, too, an hypothesis or theory in science is only of value in so far as it can be made a stepping stone to more complete knowledge. A theory which does not lead out by inference and prediction to something as yet unknown is merely a cul de sac. Having found a fruitful hypothesis, therefore, one that not only covers the known facts but by logical deductive reasoning leads us to penetrate further into the unknown by pointing to certain phenomena which ought to be observable, or to certain results which should follow from certain causes, or to the existence of something hitherto unsuspected - having formulated such an hypothesis the next stage in the scientific method is to

subject this hypothesis to crucial tests. Look for the thing the existence of which the theory predicts; carry out experiments to see if the logical results follow from the causes according to expectation; put your theory to the most severe and exacting tests that your knowledge and experience can suggest. What will be the result? Perhaps you will be convinced that the theory is untenable in the light of the new facts thus ascertained. Another and more consistent theory must then be sought. But perhaps the theory will be triumphantly vindicated, all the new facts confirming it. If so further deductions in the light of the newly established facts or relationships are sought for and being found they in their turn are put to the test. What most often happens is that the results of further investigation partly confirm and partly conflict with existing hypotheses. This calls for careful, deliberate, sometimes drastic modification of the basic theories. The new or the enlarged or the modified theory, as the case may be, is then subjected to the same critical scrutiny and its implications to further observational or experimental test ------- and so on ad infinitum.

A most important and significant point to be borne in mind is this: Science is never ashamed of having modified a theory or even of having laid aside one theory in favour of a totally different one. Science welcomes change, hailing it as a triumphant mark of progress, and with a great optimism and untiring enthusiasm the man of science grasps at a new outlook, new theories and hypotheses, as providing fresh vistas through the cloud-enshrouded wilderness beyond which lies the Truth. Why has Religion in the past dreaded and opposed change? Professor A. N. Whitehead has written, "Religion will not regain its old power until it can face change in the same spirit as does Science".

III.

What is Religion? The Oxford Pocket Dictionary says it is the system of faith and worship; human recognition of superhuman controlling power and especially of a personal God entitled to obedience; and the effect of this on conduct. One of the Greek philosophers - was it not Plato? - defined religion as the recognition of all our duties as divine commands.

In his book "Religion in the Making", Dr. Whitehead says, "There is no agreement as to the definition of religion in its most general sense, including true and false religion; nor is there any agreement as to the valid religious beliefs, nor even as to what we mean by the truth of religion." He proceeds to compare and contrast an arithmetical relationship with a doctrine of religion, and he writes, "No one is invariably 'justified' by his faith in the multiplication table. But in some sense or other, justification is the basis of all religion. Your character is developed according to your faith. This is the primary religious truth from which no one can escape. Religion is force of belief cleansing the inward parts. For this reason the primary religious virtue is sincerity, a penetrating sincerity. A religion on its doctrinal side can thus be defined as a system of general truths which have the effect of transforming character when they are sincerely held and vividly apprehended. In the long run your character and your conduct of life depend upon your intimate convictions". And further, "Religion is what the individual does with his own solitariness..... if you are never solitary, you are never religious. Collective enthusiasms, revivals, institutions, churches, rituals, bibles, codes of behaviour, are the trappings of religion, its passing forms. They may be useful or harmful; they may be authoritatively ordained,

or merely temporary expedients. But the end of religion is beyond all this." In a more mystical mood he writes of religion, "It is the vision of something which stands beyond, behind, and within, the passing flux of immediate things.....The worship of God is an adventure of the spirit."

It is perhaps hardly fair to take one sentence of the above, that sentence involving the word "solitariness", as does Dr. Charles Gore, and criticize the author for giving a very imperfect and inadequate definition of religion in that sentence. It is one of four sentences in which Dr. Whitehead crystallizes four mutually dependent ideas or partial aspects of religion. But the late Bishop of Oxford makes a strong point when he insists on the social aspect of religion. A man's attitude towards and dealings with his fellow men are the truest indication of his inmost convictions. Religion finds a higher form of expression in kindly service to humanity than in the extatic vision of the recluse; but surely it is equally true that the former activity will wear itself out if the spirit be not replenished by tapping the fountain head of spiritual inspiration in the quiet of solitude. 'As a man thinketh in his heart, so is he."

Many writers have discussed religion from this point of view, that all forms of religion whether of the most primitive or of a higher type, have as their common basis the recognition of the sacredness of some idea whether that idea be or be not associated with a material object.

To turn the searchlight of critical enquiry upon religion, in the scientific spirit, is therefore to ask and to attempt to answer the question: Is this fundamental assumption that something is sacred a justifiable premise and if so what are the logical inferences?

IV.

Let us now consider some of the contrasts and some of the analogies between science and religion. As we have already seen, sincerity of purpose, honesty of thought and open mindedness are the sine qua non in the pursuit of both science and religion. Science, and throughout this paper we are restricting the word to the physical sciences, deals with everything that is measurable. The attempt is made to describe and relate all the phenomena of the physical world in mathematical form or symbolism, the three fundamental units being mass, length, and time. The more completely the physicist succeeds in this task, the more completely does he build up a mathematically logical, symbolic counterpart of the sensible aspects of the actual world. A map of the earth's surface will exhibit certain features with extreme accuracy, will of necessity distort others and entirely omit many more. It can, therefore, in no sense be regarded as a true model of the earth. It has its uses but more must not be claimed for it than the inherent limitations will permit. So, too, the symbolic world which the physicist constructs from his measure numbers, embodying the laws and relationships existing between them, may be regarded as a map, but in no sense as a complete model of the world. Some features - the measurable ones - are accurately represented, ~~other~~ Some features of necessity or perhaps because of existing limitations of knowledge are distorted; other features are inevitably omitted. These other features, which can never be reduced to measure-

ment in terms of mass, length and time - such things as beauty, love, joy, friendship, goodness, motives - these features form a vast realm of human experience, a Happy Hunting-ground in which the physicist using the weapons of the laboratory will never run his quarry, Truth, to earth. This realm is the hunting-ground of the philosopher and of all who seek spiritual truth.

"We all know", says Professor Sir A.S. Eddington, "that there are regions of the human spirit untrammelled by the world of physics. In the mystic sense of the creation around us, in the expression of art, in a yearning towards God, the soul grows upward and finds the fulfilment of something implanted in its nature. The sanction for this development is within us, a striving born with our consciousness or an Inner Light proceeding from a greater power than ours. Science can scarcely question this sanction, for the pursuit of science springs from a striving that the mind is impelled to follow, a questioning that will not be suppressed. Whether in the intellectual pursuits of science, or in the mystical pursuits of the spirit, the light beckons ahead and the purpose surging in our nature responds."

Both in science and in religion then, it is an urge from within our own consciousness that <u>starts</u> the ball rolling. Furthermore both in science and in religion it is faith that <u>keeps</u> the ball rolling - faith that the quest of truth is worth while ; faith that there is an underlying Order in Nature, that there is a discoverable harmony in the spiritual and in the natural world. "Faith in reason", says Professor Whitehead writing on the origins of modern science, "is the trust that the ultimate natures of things lie together in a harmony which excludes mere arbitrariness. The faith in the order of nature which has made possible the growth of science is a particular

example of a deeper faith." "Of course we all share in this faith. (this instinctive faith) and we therefore believe that the reason for the faith is our apprehension of its truth."

Compare with this the appeal of Dean Inge, "Trust in reason which rests really on faith in the divine Logos, the self-revealing soul of the Universe."

A primary urge, a sustaining faith and a reliance upon reason are thus seen to be common to both science and religion. Furthermore each finds room for intuition. A flawless proof is a mathematical ideal, closely approached but not always fully attained even in pure mathematics, much less in physics. "In science", says Eddington, ~~(M.P.W. p.337)~~ "we sometimes have convictions as to the right solution of a problem which we cherish but cannot justify; we are influenced by some innate sense of the fitness of things. So too there may come to us convictions in the spiritual sphere which our nature bids us hold to..... We have to build the spiritual world out of the symbols taken from our own personality, as we build the scientific world out of the metrical symbols of the mathematician."

Weyl also

* ------- p.86

The man of science does not scorn to fall back upon some intuitive knowledge as to the direction in which truth is to be sought, the seeker after spiritual truth must rely on this inner sanction altogether, for flawless proof is, I believe, absolutely impossible in this realm. We must ~~Do~~ not make a fetish of this word <u>proof</u>. Theology has constructed many attempted proofs of the existence of God. Augustine constructed an extraordinarily interesting and ingenious proof of his own individual existence. All these are examples of mental gymnastics valuable in their place, but like an attempted proof of some physical theory they are absolutely unconvincing unless substantiated by experiment. This in science is an

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Two of the most outstanding mathematical thinkers of our day have recorded their dependence upon intuition in a very striking manner. Professor Hermann Weyl, in his masterly book, "Space, Time, Matter", attempting to derive from "world-geometry" not only gravitational phenomena, as in the pioneer work of Einstein, but also the full range of electro-magnetic phenomena, finds himself thrown back upon intuition at the very outset of his task -- here are his own words, "To bring about the transition from affine to metrical geometry we must once more draw from the fountain of intuition." Another example is to be found in the recent scientific papers of the Abbé Lemaître of Louvain who has stepped suddenly into the front rank of cosmologists with his theory of the expansion of space. Referring to one particular line of mathematical reasoning, he writes, "This method provides a very intuitional way of considering the equations of the universe."

Cont'd on p. 8a. The man of Science ....

intrinsic part of the scientific method. Is this method applicable also in religion? In a very real sense, yes. There is such a thing as experimental religion. John Wesley laid great stress upon this. The evidence of transformed lives upholds it. A Saul becomes A Paul in broad daylight in the midst of a wide awake Palestine. A John Bunyan, the ~~drunken~~ careless waster, becomes Bunyan the ~~Pilgrim~~ portrayer of a life-long pilgrimage towards Truth Righteousness. In the midst of 17th century England, ~~and~~ There are men walking the streets of our cities today, respected and esteemed, who are living witnesses to the reality of some religious impulse having the power to transform character. This appeal to experience known as Experimental Religion, with its close analogue in the experimental tests which form a part of the scientific method, is not only evident in the extreme cases of totally regenerated lives but in the everyday experience of those to whom religion is vital and for whom the Christian doctrine of Complete Sanctification is a high ideal. "There are some", says Professor Eddington, "to whom the sense of a divine presence irradiating the soul is one of the most obvious things of experience..... The most flawless proof of the existence of God is no substitute for it."

V.

In both science and religion there must be imagination if there is to be progress towards truth. But whereas science is frequently criticized, and very unjustly, as being lacking in the imaginative qualities, religion is criticized, and sometimes with good reason, for being too imaginative. Science is not a prosaic, mechanistic, unimaginative branch of human thought - the greatest men of science in every age have been the men of vision, possessed of winged imaginations, which have carried their thoughts high up above the dark clouds of ignorance and uncertainty until some ray of light is

seen pointing the direction towards the full light of truth. Dean Inge, unlike so many contemporary men of letters, understands this spirit of the scientific enquirer when he writes, "The dramatic fancy which creates myths is the raw material of both poetry and science". Of course imagination unbalanced by sane, honest, critical judgment is always dangerous, and leads to fanaticism. From this type of person science has suffered as well as religion, but to a lesser degree. But without the spark of imagination there can be no inspiring vision, no rising out of the common ruts of thought either in science or in art or in religion.

Imagination is also essential as an antidote to intolerance. Intolerance is a vice more common in religion than in science. "Theology as well as astronomy may be Ptolemaic", wrote Principal A. M. Fairbairn of Mansfield College, Oxford. "It is so when the interpreter's church, with its creeds and traditions, is made the fixed point from which he observes and conceives the truth.....But Theology may also be Copernican....."

This matter of creeds is apt to be a great stumbling block. Remember how the man of science regards his theories - a theory is a tool, not a creed. This word creed has by usage come to signify a fixed, unchanging and unchangeable belief. It should never have acquired this meaning. It should never be regarded as an end in itself. A creed, or statement of belief, in religion is of value only as it forms a stepping stone to a further revelation of spiritual truth. If the worship of God ~~is~~ be an adventure of the spirit, it is not a mere repetition of fixed beliefs regarding a completed revelation of truth - an adventure is a striving out after something as yet unknown. "Who strives without ceasing, him we can save" is the final wisdom of Goethe in his second part of Faust, while Professor Eddington writing in a similar vein, says, "How difficult to convey

the scientific spirit of seeking which fulfils itself in the tortuous course of progress towards truth! You will understand the true spirit neither of science nor of religion unless seeking is placed in the forefront."

VI.

It is a matter of experience that the more closely any event is examined the greater the number of contributing factors that are found to be involved. Science would make very little progress if it sought immediately to relate all the factors involved in any phenomenon. There must be a process of sorting out of the main factors and a deliberate placing upon one side, at least for the time being, of the factors that are regarded as of secondary importance. This recognition of what is essential requires keen scientific insight - indeed one of the highest marks of genius is seen in just this connection, the unerring, intuitive recognition of the essential features of any situation.

In the pursuit of religious truth this intuitive discrimination between the essential and the inessential is of paramount importance. Thus in attempting to apply the scientific method of investigation in the realm of spiritual enquiry, it may be necessary to set certain questions completely upon one side, not forgetting their existence, not dogmatically denying the possibility of their greater importance at some future time when new knowledge may show them up in a clearer light, but not allowing them in the meantime to obscure the main issues. In this catagory of non-essential problems, we might, for example, place the problem of miracles. Belief or disbelief in the literal truth of the miracles of the Bible does not separate the sheep from the goats, the just from the unjust. This

problem pales into insignificance compared with what is, I believe, the essential and central problem of all religion - How should a man live, and towards what end?

Success in life is a universal ambition of mankind. We want the zest of life, adventure and achievement, and if we are wise we want also peace of mind and conscience. Ruskin has said that he only is advancing in life "whose spirit is entering into <u>living peace</u>". The founder of one great religion made two tremendous assertions, not contradictory but complementary, when he said "I came that ye might have life and that ye might have it more abundantly" and again, "Peace I leave with you, my peace I give unto you."

Let us adopt Ruskin's expression "living peace" as representing the perfect blending of these two ideals. We may easily be misunderstood, however, for such an expression as this can be distorted to mean almost anything from the extreme of high pressure, intensely active life with next to no peace of spirit, to the opposite extreme of selfish, contemplative peace undisturbed by the press and surge of life around. It is here interpreted as that balance of life in which there is full participation in the great struggle and game and fight of life but at the same time a sanction of conscience that the ideals towards which life is leading are of intrinsic value, that the mode of advance is worthy of the aim, that the highest things which the human spirit is capable of appreciating are not being crowded out.

Thus interpreted, living peace is a worthy ideal, and something within us assures us that it is an ideal the attainment of which ~~is worth~~ will justify great effort. How can it be attained, this almost universal aspiration after living peace? Nineteen centuries ago the world's greatest religious teacher made the startling statement, "I am the Way, the Truth and the Life".

Now what would be the scientific attitude of mind towards this? Here is a religious theory. I shall not call it a creed, that by following the example and teaching of Christ we may live more fully and richly and experience this living peace. The scientific method of procedure is very clear. Here is a theory, however improbable it may seem, nothing is impossible, and it is a theory that fulfils one of the essential requirements of a scientific theory in that it may be put to the test of experience. That it involves incidental mysteries- the mystery of Godhead, the mystery of Incarnation, the mystery of personality, is no reason to refuse to make the crucial test. Science itself is surrounded on every side by mysteries. Mystery should challenge us, not depress and baffle us. Following the scientific method,

therefore, you would gather together all the relevant facts about the mental and spiritual outlook of Christ, the influence of his example on those who also have striven to attain this ideal and you would with honesty, sincerity, and whole hearted persevearance, not laying aside your critical faculties, put the theory to the test in your own life.

It might be regarded as strong evidence that the claim of Christ is not without foundation if as a result of your crucial test you found yourself entering into living peace.

There are those who would state with confidence that this experiment, sincerely and persistently tried, cannot fail. This is no place to argue that contention, and in any case such argument would be futile. But in regard to these great ideals of the spirit of man,—truth, beauty, righteousness,—there is a court of appeal higher than the pragmatic court of experience. In science we just touch on the edge of this when we speak of that scientific intuition as to the direction of the truth, which may remain unshaken in spite of apparent inability to prove the particular point by logic and by experiment. In the realm of religion, the realm of ideals, this rises into the noblest attribute of the human spirit - the final court of appeal between truth and falsehood, right and wrong, is within man's own individual consciousness; and with an audacity, unexplainable in terms or anything less than divine inspiration, he will fling to the four winds all short-sighted pragmatism, staking his all upon the conviction that "because right is right, to follow right

Were wisdom - in the scorn of consequence".

WONDER IN NATURE

.....

I

Out of the depths of a far distant past there has come down to us the record of the unceasing efforts of men to dispel the mists of ignorance, to penetrate further and further into the hidden places of nature, "to sail beyond the sunset" into that mysterious, shadowy borderland between the known and the unknown.

[redacted]

[redacted]

"Behold I shew you a mystery!" Nature has been proclaiming these words unceasingly since first man as a conscious, thinking being appeared upon the earth, and throughout all the ages the lure of mystery has been unfailing. It is more than a lure, it is a challenge - a challange that has led the deepest thinkers of every age, the philosophers and men of science, [redacted] with adventurous [redacted] enthusiasm to engage upon the exploration [redacted] of mystery, and the quest after truth. What is truth? Like Pilate of old we may be unable to define it, but it is a high ideal towards which it is our faith that human knowledge is gradually approaching.

Mystery in nature! It is omnipresent and it is universal in its appeal. The child in the nursery whose little mind is just commencing to grapple with some of the problems of the universe, the youth rejoicing in prowess of mind and body, the man with four score years of rich and varied experience behind him, the scholar with trained intellect, and the unlettered peasant - all are alike attracted by mystery because curiosity is one of the most fundamental and universal characteristics with which the mind of man is endowed. In the minds of the greatest thinkers and investigators this curiosity is accompanied by a

powerful, vivid, adventurous imagination, a sane, honest, logical, and critical insight, and a profound faith that beneath and behind the apparently mysterious phenomena of nature there is law and order and reason. Seek and ye shall find, knock and it shall be opened! But what do we find ? and what does the opening of the door reveal? - Further mystery, and a wider horizon with a panorama of new marvels to excite the wonder and the admiration of the explorer. And even while he pauses a moment in wonder, he feels anew the challenge of the unknown. What is just beyond the new horizon? Thus has knowledge advanced with the passing of the years.

This is true of every branch of human knowledge and it is particularly evident in the history of the sciences - biology, the mystery of life in all its various forms, animal and vegetable, visible and microscopic; chemistry, providing an inexhaustible revelation of atomic and molecular affinities; geology, with its marvellous record of the history of the earth, movements, convulsions and crumplings, uplifts and subsidences, the forces of erosion, climatic changes, the dawn of life and the development of forms of life both extinct and extant; physics, the study of energy in all its manifestations, radiant energy and bound energy as in the ultimate constituents of matter, the electron and the proton;

astronomy, the study of the stars and the starlight, of the solar system with its planets and satellites, of the immense regions of gaseous nebulosity, of the myriad star galaxies sprinkled throughout this vast universe, and of the fundamental mystery of space and time.

II

From earliest times the heavens must have excited the wonder and the admiration of men. In the stars they found two very important things - time and direction. The movements, or apparent movements, of the stars, the sun, the moon, ~~these~~ provide the time-pieces by which man has always regulated his life. The relative positions of the stars provide the finger-posts by which men shape their course on sea or on land. But their curiosity was challenged by the mystery of the universe and in every community no doubt there were men set apart and entrusted with the task of observing the sky with care and precision. The western world owes a tremendous debt to the thinkers and star gazers of the Euphrates valley.

For many centuries before the rise of Greece, the heavens had been studied with much diligence by the Chaldeans and the other wise men of Babylonia. Three or four thousand years before the time of Christ, they

had mapped the heavens and plotted the apparent motions of the sun, the moon and the five planets visible to the naked eye, Mercury, Venus, Mars, Jupiter and Saturn, against the background of the seemingly fixed stars. With amazingly vivid imaginations these ancient star gazers had identified various groups of stars or constellations, with animals, birds, dragons, fish, giants, and other mythical figures. One group of these constellations was of special interest and importance because it covered the broad belt around the sky in which the seven exceptional heavenly bodies (sun, moon and five planets) were always to be found. This great belt is called the Zodiac. So exact were the Babylonian observations of the apparent motions of the sun and moon and planets against the background of the star groups of the Zodiac that they could predict such events as eclipses of sun or moon, times of high or low tide, with ~~extreme~~ some degree of accuracy; and due to the computations of such men of high scientific attainment as Naburiannu and Kidinu it was known that the cycle of lunar phenomena repeated itself every fifty-four years and one month.

All this knowledge as well as a great mass of unexplained observations of planetary positions came into the hands of Aristotle about 300 B.C., and the keen Greek minds at once began to construct a geometrical model of the universe to account for these motions. Even a

casual observation of the heavens shows that the sun and moon move eastward relative to the almost unchanging background of the stars, but the planets move with less apparent regularity - sometimes eastward and sometimes westward. To portray these motions the early Greek astronomers had imagined the sun, the moon and each of the planets to be imbedded in a crystal sphere, one sphere for each. The outermost sphere was supposed to be the one in which all the stars were fixed, and as each of these eight spheres had to rotate about the earth at a different speed, and not always at a constant speed, there was inevitably a friction between their surfaces which was the cause of the mythical music of the spheres, so delicate, so exquisite that the ear of the ordinary mortal man could not detect it.

The later Greek astronomers elaborated the geometrical model by introducing epicycles and placing the earth slightly away from the centre of the revolving spheres. These conceptions dominated thought for over seventeen centuries and though they were ultimately shown to be fallacious, nevertheless, this belief in the rythmic, harmonious movements of the heavenly bodies, giving rise as it did to the idea of the music of the spheres, was no idle fancy. After Copernicus had propounded the theory that the Sun was the centre of the planetary system, the earth being simply one of the minor planets; and after Galileo about the year 1610

had made observations strongly supporting this heliocentric theory, John Kepler established for all time the rythmic harmony of the solar system. As a result of his almost superhuman efforts in examining the observations of the times and positions of the planets, made and collected during the long life of that picturesque astronomer, Tycho Brahe, it was given to Kepler to discover three remarkable laws, the mathematical simplicity of which both astonish and delight the mind of man even as does some unexpected sequence of simple chords which may be found to form the basis of an elaborate and complex symphony.

Kepler's first law states that the orbit of every planet is an ellipse, the sun being at one of the foci. Now the conic sections - circle, ellipse, parabola, hyperbola - had been thoroughly studied in Greek times and so geometers feel very much at home when considering planetary orbits. Kepler's second law showed that while the planets do not move with uniform speed in their orbits, there is nothing uncertain or haphazard about their motions; the radius vector, or line joining sun to planet, sweeps over equal areas in equal times. This means that every planet speeds up as it passes nearest to the sun and gradually slows down as it recedes from perihelion towards the more remote part of its orbit. So, too, the comets moving slowly on the outskirts of the solar system

are obedient to the same fundamental law, their velocities increasing as they approach the sun round which they pass at their maximum speeds again to withdraw at lesser and lesser velocities.

The third law discovered by Kepler is often referred to in terms strongly suggestive of music - the harmonic law:- [redacted] the squares of the periodic times of the planets vary as the cubes of their average distances from the sun. And then as the crowning glory of celestial mechanics, the Newtonian law of gravitation supplied the missing factor of proportionality, namely, the sum of the masses of sun and planet. Here, truly, is an heavenly lyric of surpassing beauty, [redacted], universal in its applicability, for whether it be Earth and Moon, or Earth and Sun, or Mars or Jupiter, or Neptune, or the multiple stars like Algol and Mizar far off in the sky, or even twin galaxies in the remotest depths of space - all revolving systems are radiant embodiments of this celestial lyric.

III.

Without the harmonic law, astronomical knowledge would be very limited. Even within our own solar system we would be unable to measure the masses of the planets, while the masses of the stars would be an insoluble mystery. With the aid of this law, astronomers have

weighed the stars, placed our sun as a very average dwarf star,found very few stars as much as one hundred times as massive and not one star as little as one tenth the mass of the sun. Here was a problem which aroused the curiosity of the astronomers. Supposing there were a time when all the matter of the entire galaxy was more or less evenly spread out as a vast gaseous nebula, then with the random movements of the individual molecules or atoms there would inevitably be formed places of greater concentration and these would act as gravitating centres of attraction. Thus stars would be gradually formed from the chaos of nebulosity, but it appears that there are upper and lower limits to the mass of the stars thus formed. How is this accomplished? By what system of weights and measures does Nature apportion out her clouds of gases to form each star - the old problem of Shylock, a pound of flesh, no more, no less - or to be more correct, not very many times more nor very much less.

The answer to this question wassupplied a few years ago by Sir A. S. Eddington, and it is but another example of the harmonious balance of natural forces, like the various parts of a great orchestra kept in control by a master musician. In the growing star threeforces are making a bid for supremacy. Gravitation tends to augment the mass of the star and increase its density indefinitely, by attracting more and more matter to the star and drawing it nearer and nearer to the centre. But the more gravitation succeeds, the hotter grows the interior of the star, like

the air compressed into a bicycle tire; and the higher the temperature the greater the kinetic energy of the atoms, hence the faster they move and the greater becomes the gas pressure tending to expand the star against gravitation. A third force likewise comes into play, more and more vigorously as temperature increases, the pressure of the radiation generated within the star. This radiation is of the nature of heat when the temperature in the star is low, but as temperature rises the ~~other~~ star will begin to glow, radiation of the wavelengths of visible light being generated within it. At still higher temperatures more and more penetrating radiations, like X-rays, are generated within, and all these radiations rushing outwards towards the surface of the star, ultimately to escape into outer space, exert an outward pressure buoying up the gases composing the star.

and calcium like spray from the surface of our sun, and radiating their distinctive lights of red and violet, these lofty clouds excite the wonder and the curiosity of the astronomer. Pressure of radiation is responsible, in part at least, for one of the phenomena which through all the ages has awakened the emotions and imaginations of men, the beautiful spectacle of the long, luminous tail of a comet. Pressure of radiation, acting with explosive violence, is probably the cause of the rejuvenation of a faint star, a phenomenon which occurs in the heavens from time to time and is usually referred to as the appearance of a "new star", or nova. What the astronomer observes is the rapid brightening of a star never previously recorded as being other than steadily faint. In the course of a few hours or days its brightness may increase many thousand fold, after which it slowly and fluctuatingly loses its brilliance again. This is in reality a cataclysm of nature of a magnitude unparalled in the whole range of scientific knowledge. We know not how or why, but in such a star there has evidently occurred a sudden liberation of vast stores of hitherto locked-up energy, and this energy being [redacted] released as radiation exerts a pressure so tremendous that it lifts layer upon layer of the star's substance and hurls it outward in all directions with terrific velocity, and the light of the star breaking from its surface and rushing headlong through the turbulent luminous clouds of ejected gases wings its

In a very beautiful 16th. century example of the art of wood-cut, there is represented the earth with its hills and valleys, its towns and its country-side with trees, plants, and animals; and over it the spherical dome of heaven containing symbolic representations of sun, moon, comets and stars. The dome of heaven rests upon a rim of high mountains, which the ancient cosmologists imagined to extend all around the earth. In the foreground the artist has portrayed a shepherd who, having climbed to the top of one of this chain of encircling mountains, has thrust his head and shoulders through the dome of heaven, and with a gesture of amazement is gazing at undreamed of marvels out beyond. The artist was evidently straining his imagination to the very utmost to conceive of wheels and spokes and strange cloud-like formations to place beyond the dome of heaven to excite the wonder of the adventurous shepherd. But how commonplace, tepid, insipid, and apparently uninspired are his imaginings compared with the actual marvels of the deep regions of space beyond the range of the human vision! By the aid of telescope and photographic plate the remote depths of space have yielded up some of their secrets, and the physicist in his laboratory collaborating with the astronomer has shown us a world of extent and grandure undreamed of in earlier years.

"Distance inexpressible by numbers that have name" - so wrote John Milton, and we recall that he visited the aged Galileo in Italy and no doubt the latter expounded to him the new views of the universe which his own observations with his astronomical telescope

had done so much to establish. No doubt, too, Milton was privileged to see the telescope that Galileo had himself invented, and to see some of the new wonders of the eternal world which no eye had seen until Galileo turned his glass upon them - the four satellites of Jupiter, the ever moving, ever changing, dark areas on the surface of the sun, the star clouds of the Milky Way. Perhaps, too, he was shown the great Nebula of Orion, that vast abyss of wildly chaotic gases, some radiating light, some dark and lowering. Is it too great a flight of the imagination to guess that such a sight, perhaps that very sight, inspired the lines in 'Paradise Lost' -

> "Behold the throne
> Of chaos and his dark pavilion spread
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With the mathematical researches of Sir Isaac Newton a new era dawned - dynamical astronomy came into being; and with the invention by Newton, in 1675, of the reflecting telescope a new tool was placed in the hands of the astronomer by means of which to carve out the picture of still greater depths of space. Sir William Herschel, and later Lord Rosse, made telescopes after the Newtonian model, which revealed the first details of the Spiral Nebulae. Here was something to excite the wonder of mankind. The Andromeda Nebula, to the unaided eye, is merely a hazy, fuzzy little patch of light like a small puff of smoke; but in the telescope it is a vast aggregation of stars arranged in spiral

arms extending out from a denser, more nebulous centre. Other spiral galaxies of stars even more striking in appearance were seen for the first time, The Whirlpool Nebula, for example. To-day, at Mount Wilson Observatory, and at Harvard Observatory, intensive study of the spirals is being carried on, more than 20,000 have been noted on Harvard photographic plates, while the spectra of the brighter ones are being obtained at Mount Wilson, and calculations of masses and distances being attempted. The nearest of these remote spirals is so far away that the light from its stars only comes to us after journeying nearly a million years.

The study of the spirals has carried us very far away from the geocentric model of the universe. Men thought the earth was the centre of the whole revolving universe; but it was not so. Later they placed the sun at the centre of the system of planets and imagined that the stars lay more or less ~~symmetrically~~ in all directions; but it was not so. Herschel began the task of making systemat ic star-counts which has been carried on with greater and greater exactitude to fainter and fainter stars until, in recent years, it has appeared that the stars of our great galaxy are arranged in a vast lens-shaped volume of space extending much further out all around one plane than anywhere at right angles to this plane, that our sun is a quite ordinary star situated well away from the centre of

the galaxy, so that looking out around us from this little planet near the sun, we see a very lop-sided picture of the galaxy. The Milky Way gives us our bearings relative to this galactic plane, but the number of stars that can be photographed in the direction of the constellations Sagittarius, Scorpio and Ophiuchus far exceeds the number in any other region. This leads to the conclusion that in that direction lies the centre of our galaxy comprising some ten thousand million suns. Perhaps many astronomers thought this was the main part of the material universe, but it was not so. Every one of the thousands upon thousands of spiral nebulae is a galaxy of millions of stars, comparable to our own galaxy.

We turn from the contemplation of the vastest things of which man has knowledge to the smallest things, the atoms and their constituents, the protons and the electrons. There is no greater achievement of the human mind than that which has revealed to us some understanding of atomic structure and atomic radiations. Heat and light from a candle, light from the electric spark that jumps from your finger to your kitten's head as you stroke her in the dark, are these phenomena worth a life long study? Assuredly the answer is in the affirmative for to elucidate these "commonplace" things, is to understand the significance of the sunshine and the secrets of the starlight.

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When we use the expression Wonder in Nature, we

mean simply that there is much in the world around us that stirs our curiosity, that excites our admiration, that lifts our thoughts from the matter-of-fact ruts in which they are apt to move and fills us with a sense of wonder, in plain words, there is much in nature that is wonderful, and here we are using the word wonderful in its original sense, for like the word "awful" it has been misused and abused until it has lost its meaning, its solemn significance - full of wonder. So too the original significance of "awful" was full of awe, producing a feeling not of terror and horror, but of deep solemnity, and this is its significance in the lines of Shelley where, in the Prometheus Unbound, Panthea and Ione are conversing thus:

Ione: "Even whilst we speak
New notes arise. What is that awful sound?"

Panthea: "Tis the deep music of the rolling world
Kindling within the strings of the icy air
Eolian modulations".

Ione: "Listen, too
How every pause is filled with under notes
Clear, silver, icy, keen, awakening tones,
Which pierce the sense and live within the soul,
As the sharp stars pierce winter's crystal air."

In earlier times men looked upon the heavens with awe, but it was an awe borne largely of ignorance and superstition, a dread that the forces of nature were hostile to man. To-day man likewise looks upward at the heavens and contemplates the universe with all its, as yet, unsolved mysteries, and he too is conscious of a feeling of awe and wonder, but it is an awe borne of certain knowledge that the

heavens declare their kinship with the earth - things celestial and things terrestrial are not two but one in the evidence they bear to the fundamental unity of all nature, the underlying harmony of the universe.

What is it that differentiates man from the beasts that perish? Surely it is just this, that he alone of created things, as far as we are aware, has the capacity to respond with feelings of awe and of reverence to mystery, whether in the realm of things spiritual or of things natural.

1932 May 5.

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Corrected copy

WONDER IN NATURE

VV.....

I

Out of the depths of a far distant past there has come down to us the record of the unceasing efforts of men to dispel the mists of ignorance, to penetrate further and further into the hidden places of nature, "to sail beyond the sunset" into that mysterious, shadowy borderland between the known and the unknown.

Original pages 6
Mrs Mercer
1932 May 9

Corrected Copy

~~MYSTERY IN NATURE~~

1

"Behold I shew you a mystery!" Nature has been proclaiming these words unceasingly since first man as a conscious thinking being appeared upon the earth, and throughout all the ages the lure of mystery has been unfailing. It is more than a lure, it is a challenge - a challange that has led the deepest thinkers of every age, the philosophers and men of science, ~~to "lay aside every weight and run with patience the race that is set before" them, dedicating their lives to the unravelment~~ To engage with adventurous enthusiasm upon the exploration of of mystery, to the quest after truth. What is truth? Like Pilate of old we may be unable to define it, but it is a high ideal towards which it is our faith that human knowledge is gradually approaching.

Mystery in nature! It is omnipresent and it is universal in its appeal. The child in the nursery whose little mind is just commencing to grapple with some of the problems of the universe, the youth rejoicing in prowess of mind and body, the man with four score years of rich and varied experience behind him, the scholar with trained intellect, and the unlettered peasant - all are alike attracted by mystery because curiosity is one of the most fundamental and universal characteristics with which the mind of man is endowed. In the minds of the greatest thinkers and investigators this curiosity is accompanied by a

powerful, vivid adventurous imagination, a sane, honest, logical, and critical insight and a profound faith that beneath and behind the apparently mysterious phenomena of nature there is law and order and reason. Seek and ye shall find, knock and it shall be opened! But what do we find ? and what does the opening of the door reveal? - Further mystery, and a wider horizon with a panorama of new marvels to excite the wonder and the admiration of the explorer. And even while he pauses a moment in wonder, he feels anew the challenge of the unknown. What is just beyond the new horizon? Thus has knowledge advanced with the passing of the years.

This is true of every branch of human knowledge and it is particularly evident in the history of the sciences - biology, the mystery of life in all its various forms, animal and vegetable, visible and microscopic; chemistry, providing an inexhaustible revelation of atomic and molecular affinities; geology, with its marvellous record of the history of the earth, movements, convulsions and crumplings, uplifts and subsidences, the forces of erosion, climatic changes, the dawn of life and the development of forms of life both extinct and extant; physics, the study of energy in all its manifestations, radiant energy and bound energy as in the ultimate constituents of matter, the electron and the proton;

astronomy, the study of the stars and the starlight, of the solar system with its planets and satellites, of the immense regions of gaseous nebulosity, of the myriad star galaxies sprinkled throughout this vast universe, and of the fundamental mystery of space and time.

II

From earliest times the heavens must have excited the wonder and the admiration of men. In the stars they found two very important things - time and direction. The movements, or apparent movements, of the stars, the sun, the moon, ~~these~~ provide the time-pieces by which man has always regulated his life. The relative positions of the stars provide the finger-posts by which men shape their course on sea or on land. But their curiosity was challenged by the mystery of the universe and in every community no doubt there were men set apart and entrusted with the task of observing the sky with care and precision. The western world owes a tremendous debt to the thinkers and star gazers of the Euphrates valley.

For many centuries before the rise of Greece, the heavens had been studied with much diligence by the Chaldeans and the ~~other~~ wise men of Babylonia. Three or four thousand years before the time of Christ, they

had mapped the heavens and plotted the apparent motions of the sun, the moon and the five planets visible to the naked eye, Mercury, Venus, Mars, Jupiter and Saturn, against the background of the seemingly fixed stars. With amazingly vivid imaginations these ancient star gazers had identified various groups of stars or constellations, with animals, birds, dragons, fish, giants, and other mythical figures. One group of these constellations was of special interest and importance because it covered the broad belt around the sky in which the seven exceptional heavenly bodies (sun, moon and five planets) were always to be found. This great belt is called the Zodiac. So exact were the Babylonian observations of the apparent motions of the sun and moon and planets against the background of the star groups of the Zodiac that they could predict such events as eclipses of sun or moon, times of high or low tide, with ~~extreme~~ considerable accuracy; and due to the computations of such men of high scientific attainment as Naburiannu and Kidinu it was known that the cycle of lunar phenomena repeated itself every fifty-four years and one month.

All this knowledge as well as a great mass of unexplained observations of planetary positions came into the hands of Aristotle about 300 B.C., and the keen Greek minds at once began to construct a geometrical model of the universe to account for these motions. Even a

casual observation of the heavens shows that the sun and moon move eastward relative to the almost unchanging background of the stars, but the planets move with less apparent regularity - sometimes eastward and sometimes westward. To portray these motions the early Greek astronomers had imagined the sun, the moon and each of the planets to be imbedded in a crystal sphere, one sphere for each. The outer most sphere was supposed to be the one in which all the stars were fixed, and as each of these eight spheres had to rotate about the earth at a different speed, and not always at a constant speed, there was inevitably a friction between their surfaces which was the cause of the mythical music of the spheres so delicate, so exquisite that the ear of the ordinary mortal man could not detect it.

The later Greek astronomers elaborated the geometrical model by introducing epicycles and placing the earth slightly away from the centre of the revolving spheres. These conceptions dominated thought for over seventeen centuries and though they were ultimately shown to be fallacious, nevertheless, this belief in the rythmic, harmonious movements of the heavenly bodies, giving rise as it did to the idea of the music of the spheres was no idle fancy. After Copernicus had propounded the theory that the Sun was the centre of the planetary system, the earth being simply one of the minor planets; and after Galileo about the year 1610

had made observations strongly supporting this heliocentric theory, John Kepler established for all time the rythmic harmony of the solar system. As a result of his almost superhuman efforts in examining the observations of the times and positions of the planets, made and collected during the long life of that picturesque astronomer, Tycho Brahe, it was given to Kepler to discover three remarkable laws, the mathematical simplicity of which both astonish and delight the mind of man even as does some unexpected sequence of simple chords which may be found to form the basis of an elaborate and complex symphony.

Kepler's first law states that the orbit of every planet is an ellipse, the sun being at one of the foci.Now the conic sections - circle, ellipse, parabola, hyperbola - had been thoroughly studied in Greek times and so geometers feel very much at home when considering planetary orbits. Kepler's second law showed that while the planets do not move with uniform speed in their orbits, there is nothing uncertain or haphazard about their motions; the radius vector, or line joining sun to planet, sweeps over equal areas in equal times. This means that every planet speeds up as it passes nearest to the sun and gradually slows down as it recedes from perihelion towards the more remote part of its orbit. So, too, the comets moving slowly on the outskirts of the solar system

are obedient to the same fundamental law, their velocities increasing as they approach the sun round which they pass at their maximum speeds again to withdraw at lesser and lesser velocities.

The third law discovered by Kepler is often referred to in terms strongly suggestive of music - the harmonic law. It reads like a verse of poetry in the ear of the astronomer - the squares of the periodic times of the planets vary as the cubes of their average distances from the sun. And then as the crowning glory of celestial mechanics, the Newtonian law of gravitation supplied the missing factor of proportionality, namely, the sum of the masses of sun and planet. Here, truly, is an heavenly lyric of surpassing beauty, delicately majectic in its entirety, graceful and stately in its rhythmic harmony, universal in its applicability, for whether it be Earth and Moon, or Earth and Sun, or Mars or Jupiter, or Neptune, or the multiple stars like Algol and Mizar far off in the sky, or even twin galaxies in the remotest depths of space - all revolving systems are radiant embodiments of this celestial lyric.

III.

Without the harmonic law, astronomical knowledge would be very limited. Even within our own solar system we would be unable to measure the masses of the planets, while the masses of the stars would be an insoluble mystery. With the aid of this law, astronomers have

weighed the stars, placed our sun as a very average dwarf star,found very few stars as much as one hundred times as massive and not one star as little as one tenth the mass of the sun. Here was a problem which aroused the curiosity of the astronomers. Supposing there were a time when all the matter of the entire galaxy was more or less evenly spread out as a vast gaseous nebula, then with the random movements of the individual molecules or atoms there would inevitably be formed places of greater concentration and these would act as gravitating centres of attraction. Thus stars would be gradually formed from the chaos of nebulosity, but it appears that there are upper and lower limits to the mass of the stars thus formed. How is this accomplished? By what system of weights and measures does Nature apportion out her clouds of gases to form each star - the old problem of Shylock, a pound of flesh, no more, no less - or to be more correct, not very many times more nor very much less.

The answer to this question was supplied a few years ago by Sir A. S. Eddington, and it is but another example of the harmonious balance of natural forces, like the various parts of a great orchestra kept in control by a master musician. In the growing star the forces are making a bid for supremacy. Gravitation tends to augment the mass of the star and increase its density indefinitely, by attracting more and more matter to the star and drawing it nearer and nearer to the centre. But the more gravitation succeeds, the hotter grows the interior of the star, like

the air compressed into a bicycle tire; and the higher the temperature the greater the kinetic energy of the atoms, hence the faster they move and the greater becomes the gas pressure tending to expand the star against gravitation. A third force likewise comes into play more and more vigorously as temperature increases, the pressure of the radiation generated within the star. This radiation is of the nature of heat when the temperature in the star is low, but as temperature rises the ~~other~~ star will begin to glow, radiation of the wavelengths of visible light being generated within it. At still higher temperatures more and more penetrating radiations, like X-rays, are generated within, and all these radiations rushing outwards towards the surface of the star, ultimately to escape into outer space, exert an outward pressure buoying up the gases composing the star.

The pressure of light! Not many years ago the most learned man of science would have said that the pressure of light was as unreal, illusory and fantastic as was the music of the spheres - an intangible figment of the imagination. But to-day the pressure of light is recognized as one of the major forces of nature. It preserves the equilibrium of the stars by balancing gravitational force; it prevents the stars from growing to abnormal size by blowing off as with a mighty rushing wind the excess gases that the rival force of gravitation would embrace and enfold with an unsatiable hunger; it tosses up clouds of atoms of hydrogen and helium

and calcium like spray from the surface of our sun, and radiating their distinctive lights of red and violet, these lofty clouds excite the wonder and the curiosity of the astronomer. Pressure of radiation is responsible, in part at least, for one of the phenomena which through all the ages has awakened the emotions and imaginations of men, the beautiful spectacle of the long, luminous tail of a comet. Pressure of radiation, acting with explosive violence, is probably the cause of the rejuvenation of a faint star, a phenomenon which occurs in the heavens from time to time and is usually referred to as the appearance of a "new star", or nova. What the astronomer observes is the rapid brightening of a star never previously recorded as being other than steadily faint. In the course of a few hours or days it brightness may increase many thousand fold, after which it slowly and fluctuatingly loses its brilliance again. This is in reality a cataclysm of nature of a magnitude unparalled in the whole range of scientific knowledge. We know not how or why, but in such a star there has evidently occurred a sudden liberation of vast stores of hitherto locked-up energy, and this energy being ~~suddenly~~ released as radiation exerts a pressure so tremendous that it lifts layer upon layer of the star's substance and hurls it outward in all directions with terrific velocity, and the light of the star breaking from its surface and rushing headlong through the turbulent luminous clouds of ejected gases wings its

way outward into the vast regions of interstellar space, - ever outward, never slowing down, on and on year after year, century after century - until in the fulness of time perchance a minute fraction of that out-streaming light falls upon the lens or the mirror of a telescope set up by man on the surface of a very small planet which ~~circles interminably about~~ revolves around one somewhat insignificant star. From lens or mirror this little glimmer of light finds itself hurtling through the prisms of a spectrograph which causes its component rays to spread out in order of wave length like the notes of a musical scale. There, in ordered array, it falls upon the emulsion of the photographic plate. Here its lond journeyings come to an end for the radiant energy becomes transformed into chemical energy - the molecular readjustments in the the emulsion which develop out as the photographic image of star light. But the transformation of energy takes place in such a way that every detail of the incoming light is retained and preserved in the photographic record. Thus it is possible for the astrophysicist to unravel the majectic story of such a star from the image of its light, just as a musician contemplating a printed score can reconstruct the full grandure and solemnity of an immortal oratorio.

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