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ATOMS GALAXIES AND UNDERSTANDING

Books by Daniel W. Fry, Ph.D.

The White Sands Incident

To Men of Earth

Step to the Stars

Atoms Galaxies and Understanding

Atoms Galaxies

and

Understanding

Cosmology in its Simplest Form

By Daniel W. Fry, Ph.D.

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INTRODUCTION

The discussions presented in this book are offered in the hope that they may assist the layman, the beginning student, and perhaps, even a few of the more advanced students of cosmology, in the achievement of an approach to the science which is based upon simple understanding rather than upon the complex and often confusing lattice-work of abstract mathematics which has been erected about it.

While it is true that the language of mathematics is a universal language, it is, nevertheless, a language which must be learned before it can be used or understood.

There are many persons in the world today who would like to acquire a greater knowledge and understanding of the nature of the universe about them, but who have never had the opportunity to familiarize themselves with the language of mathematics to a degree that would permit them to follow the paths through which this knowledge is customarily presented.

It was principally for these persons that this book was written. Consequently, simple discussion, explanation and analogy will be substituted for mathematics, to the greatest possible degree. We will risk, thereby, the scorn of the mathematician, but may gain the gratitude and the comprehension of the non-math student.

Much of the material presented in these pages was taken from a series of lectures originally written for the Great Western University, and from the book, "Steps to the Stars," which was first published some years ago, but whose basic concepts are only now beginning to be accepted by cosmologists.

Since the study of cosmology embraces the microcosm as well as the macrocosm, we will begin this text with a consideration of the most minute and fundamental particles of nature, insofar as they are known and understood today. We will examine the forces which bind these particles together, but which may also, under certain circumstances, hurl them violently apart.

Physicists may criticize the book as being over simplified, yet as we continue our examination of its text we may find, to our surprise, that most of the innumerable laws or rules of physics, which have been learned through so many years of patient observation, test, and interpretation, may actually be predicted by the reader, even though he may never have heard of those laws or observed them in operation.

CHAPTER ONE

DEFINITIONS

The art of teaching is simply an orderly process of conveying knowledge or information from one mind to another. This process is carried on principally by the use of the spoken or the written word. Since it is the word that conveys the concept from the mind of the teacher to that of the student, it is obvious that if the teaching is to be successful, the words used must have exactly the same meaning for the student that they have for the teacher.

In cosmology, as in any field of advanced thought, there are a number of words which must be used, but which have never been very successfully or very precisely defined. Consequently, the first step in the presentation of a series of discussions upon this subject should be the formulation of a set of definitions for these words, so that the mind of the reader may create an accurate reproduction of the concept in the mind of the author.

The following definitions should be examined and considered carefully by the reader before beginning the

text of the book, since if the meaning of these terms is not precisely understood by the reader, the text may fail in its primary purpose.

REFERENCE POINT - A reference point is defined as being one of two or more predetermined and specified points, between which, measurements are to be made.

MOTION - Motion is defined as a continuing change in the relative position of a given object or reference point, with respect to the observer, or to some other object or reference point.

Everyone has a tendency to think of motion as being something absolute. Either a body moves, or it does not move. Yet, if we look about us at the universe, we find that every body of matter in that universe is in motion. They are all in motion with respect to us, and each of them is in motion with respect to every other body. Where can we find a reference point from which to determine absolute motion? It must be understood that when we speak of motion, we are using a purely relative term. When we say that an object is in motion, we mean only that its position is changing with respect to us, or to some other specified object, or point of reference.

VELOCITY - Velocity is defined as the rate of motion. It is measured by the amount of change in position which occurs in a given unit of time. In the case of automobiles,

aircraft or other vehicles, velocity is usually measured in miles per hour. In physics it is almost always measured in centimeters per second. Whatever the unit used for its measurement, however, we must always remember that if it is to have any significance, the measurement must be made from a specified point of reference or observation. For example, we can easily see that a man seated in his easy chair at home, has zero velocity with respect to the earth, but considerable angular velocity with respect to the moon, a much higher velocity with respect to the sun, and a different and still higher velocity with respect to each of the countless stars in the known universe.

ACCELERATION - Acceleration is defined as a change in the existing state of motion. It can be either positive or negative. That is: if the observed velocity is increasing, the acceleration is said to be positive. If the velocity is decreasing, the acceleration is said to be negative. (The word deceleration is sometimes used to indicate a decreasing velocity, but the term negative acceleration is generally considered to be more proper.) Example: If a certain automobile were to 'speed up', from ten miles per hour to sixty miles per hour in a period of ten seconds, we would say that its velocity had increased at a rate of five miles per hour during each second of acceleration. We would indicate this by saying that its acceleration was equal to five miles per hour, per second. In physics, acceleration is

usually measured in meters or centimeters per second, per second. In mathematics this is usually written - Cm/S/S or Cm/S^2.

ENERGY - We will define energy as the ability to create changes in the position or condition of objects or points of reference. However, energy can create change, only when there exists a differential in the two points between which the change becomes manifest, or when the unit of energy has become divided into its two component parts called poles or charges. One positive and one negative pole or charge; when united, constitute one photon or quantum of energy.

FIELD - A field is an area of influence which surrounds the poles of energy when they are separated. The field manifests itself as a force which tends to increase the distance between like poles or charges, and to decrease the distance between unlike, or pairs, of poles or charges. The field is usually divided into three general types, the Electric Field, the Magnetic Field, and the Gravitational Field. The three types, however, are simply special case manifestations of the field principle, and all three result from the division of energy into its two component parts.

MASS - Mass is a property which is usually associated with matter, but which is also found to be associated with energy. It is defined as the property of resistance to acceleration,

and is measured by the amount of force required to produce a given rate of acceleration.

These definitions will probably be sufficient to begin our consideration of the microcosm. Others will be given as required by the text.

CHAPTER TWO

THE BUILDING BLOCKS

We will begin our examination of the universe by considering, briefly, the nature of four of its most minute and fundamental entities: the neutron, the proton, the electron and the photon (or quantum of energy). No man has ever seen any of the four. So minute are they, that the most powerful microscope ever made could not begin to resolve them. Yet all of the matter in the universe is composed of the first three, and all of the changes which occur in that universe come about as a result of the action of the fourth.

In order to achieve a basic understanding of the nature and properties of the electron, the proton and the neutron, we will arbitrarily create or assume a fourth particle which we will call the 'nullatron'. We will postulate that this particle has no charge, possesses no energy, and consequently is not associated with any type of field. In fact we will assume that this particle has no property other than that of inertial mass, or resistance to acceleration. We hasten to confess that, so far as we know, no evidence of the existence of such a particle is available in

our present technology and, because of its dearth of properties, its existence would be exceedingly difficult to demonstrate by any presently known method. Nevertheless, the assumption of such a particle offers an ideal starting point in our examination of the nature of matter, and so we will assume the particle, if only to serve as an aid to understanding.

If, to the nullatron, we add a photon or, as it is more usually known, a quantum of energy, in such a way that the energy is entirely contained within the particle, (See illustrations on following page.) we will find that the particle has acquired several additional properties. In adding the quantum of energy, we have supplied the particle with both a positive and a negative charge. (See definition of energy.) Since these charges are united within the particle, there will be no exterior electrical field, but a gravitational field will be created. This particle, which now exhibits the properties of inertial and gravitational mass, has been named the neutron. Its existence was demonstrated in 1932 by Sir James Chadwick, an English Physicist.

If we could find a means of dividing the quantum of energy into its two component parts, and of drawing the negative charge our of the body of the neutron, so that the charge formed a shell of force around the core, we could convert the neutron into the simplest of all atoms, the atom of the element which we call Hydrogen. The simple

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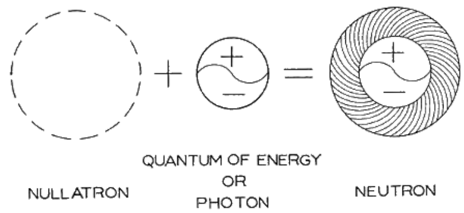

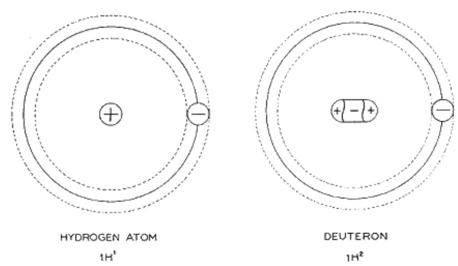

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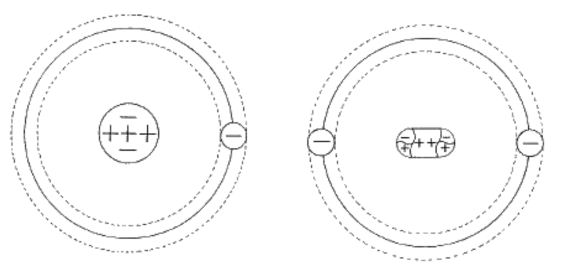
particle has now become a rather complex mechanism. The central core which retains almost all of the mass, and from which the gravitational field still emanates, now has a positive electrical charge, and is known as a proton. The shell of force, which consists entirely of the negative portion of the quantum of energy is known as an electron.

In most of our textbooks today, the electron is represented as a small particle in a precise orbit about the proton in much the same manner as the earth orbits the sun. While this analogy works fairly well as long as we confine our study to the field of chemistry, if we attempt to explain all of the observed properties of matter by nuclear hypothesis, we will find that we require a somewhat more complex analogy.

Let us, therefore, attempt to create such an analogy, remembering that, like the nullatron, it is created only as a tool of understanding. We will begin with the usual concept: a small particle in a simple orbit around the proton. We will then assume that the electron is extended or `stretched out' along the path of its orbit until it becomes a ring of charge occupying, simultaneously, all parts of its orbit, but still having the same rotational, or angular velocity. If we now rotate the ring upon an axis which passes through the proton and two opposite points in the ring, we will create a sphere of charge about the proton which is uniform in density but characterized by precise angular velocities about each of the two axes. While the assumption of these angular velocities is not particularly important in our first approach to the nature of matter, they do become necessary to the explanation of some of the more complex phenomena such as crystallization in solids, diffraction of light, etc.

Having examined the atom from inside outward, as it were, by theoretical creation, we should now be better prepared to examine it from the outside inward, as we shall presently proceed to do.

We must remember that the atom which we have created is the simplest of all the atom family. It is known as $_1H^1$ or 'normal' hydrogen.



TRITON $_1H^3$ HELIUM $_2HE^4$

If we add a neutron to the proton which is at the center of this atom, we create a particle called $_1H^2$ or deuterium. This atom is still hydrogen and has chemical properties identical with those of $_1H^1$. The mass and weight, however, are now twice as great. For this reason, $_1H^2$ is frequently referred to as heavy hydrogen.

If we add a second neutron to the nucleus we will have $_1H^3$ tritium. It is still chemically identical with $_1H^1$ but has three times the mass. It is sometimes known as heavy, heavy, hydrogen.

It becomes apparent that the chemical properties of the element are determined by the number of electrons in the shell and the number of protons in the core.

In the three types of atom which we have considered, each contained one electron and one proton, and all are therefore considered to be atoms of the same element. They are known as Isotopes of the element.

If we attempt to add a third neutron to the nucleus, we will find that the field condition within the atom is now such that a considerable amount of force will be required, and that the act of forcing the neutron into place will cause its quantum of energy to divide spontaneously. The negative charge will be emitted from the neutron, and as a second electron, will join the first in the shell of force surrounding the atom. The remaining portion is now positively charged and so becomes a proton.

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The atom now contains two electrons, two protons and two neutrons. We have created an atom of the second element in the series, called Helium. Its name was taken from the Greek word 'helios' (The Sun) because it was discovered by spectrographic analysis of the sun's atmosphere a quarter of a century before it was discovered on earth.

In symbolic terminology, this atom is described as ${}_2HE^4$ The letters represent the name of the element, the number preceding the letters gives the number or orbital electrons, and the number following the letters gives the total number of protons and neutrons contained in the nucleus.

If we continue (theoretically) to build up our atom by the addition of neutrons, we will find that, in each step of the process, we can create a certain number of isotopes. That is, we can add a certain number of neutrons without changing anything but the mass of the atom. If we exceed this number, the force required to insert the next neutron will cause it to emit the negative portion of its charge, becoming a proton and adding another electron to the shell. Thus the next higher element in the atomic scale is formed. If we continue this process long enough, we will eventually have created atoms of all the known elements, and all of their possible isotopes.

In building the next element after helium, that is: lithium, we would have to insert two neutrons simultaneously,

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since there is no known combination of five nuclear particles which will remain together for any appreciable time.

We have described this addition of neutrons to the nucleus as though it were a simple process. Therefore, lest the reader be misled we will hasten to state that we have no means in our present technology of forcing a consecutive series of neutrons into the nucleus of a single atom, and that if we did have such a means, we would find that remarkable changes in energy level would occur during some stages of the building process, resulting in the emission of considerable electro-magnetic radiation, and the loss of a small part of the mass of the atom, even though all of its particles were still present. There are, however, some transmutations of elements which we can, and do, achieve by the simple addition of neutrons. The conversion of Uranium 238 to Plutonium is one example.

It should also, perhaps, be mentioned at this point, that the number of electrons which will occupy a single shell of force is limited. If, after a shell containing this number of electrons has been formed, more electrons are emitted from particles within the nucleus, they will not be absorbed by the shell but will pass through it, to form a second shell outside the first, and so on.

Let us now expand our scale of observation for a moment so that we may consider a drop of ordinary water. If we divide the drop into two equal parts, we will find that

each of the two parts retains all of the properties which were possessed by the original drop. Each of the parts is still water. We might repeat this division many times without changing anything except the size of the parts, but eventually we would reach a particle which could not be further divided without producing a complete change in its properties. This particle is called a molecule and is defined as being the smallest particle of a complex substance or 'compound' which can exist as that compound.

A molecule is composed of two or more atoms which have come together in such a way that some of the electrons in the outer shells have expanded their orbit so as to create a new shell which encloses all of the atoms. The several atoms will then behave to some extent as though they were one.

If we divide the molecule of water, we find that it is composed of two atoms of our simplest element, hydrogen, and one atom of a somewhat more complex element called oxygen.

The word 'atom,' as related to particles of matter, originated in the philosophy of ancient Greece. In the fifth century B.C., the Greek Philosophers, Democritus and Leucippus, set forth the postulate that all substances are built up of small units which are not capable of further division, They named these particles Atoms, a word meaning indivisible.

It is one of the peculiarities of the progress of human knowledge that, although this theory was enunciated more than two thousand years ago, it is only within recent years that we have come to accept fully the first portion of this concept, and at the same time we have worked vigorously and successfully to disprove the latter portion. We have demonstrated that the atom is not an indivisible particle, but is actually a complex mechanism made up of a number of cooperating parts.

The parts are exceedingly small, even in comparison to the size of the atom. In the diagrams used in this book, the dots or circles used to represent the protons and the neutrons are much too large in proportion to the size of the orbit. If they were drawn to true scale, they would be invisible except under the most powerful microscope. The volume occupied by the nucleons (nuclear particles) is considered to be about one million trillionth of the total volume of the atom.

We can see that the atom is far from being the solid, indivisible particle which the Greek Philosophers imagined. Indeed, the atom is practically all space! It is, however, a space which is filled with powerful fields, and it is the operation of these fields that makes the atom behave as though it were a solid, indestructible particle.

CHAPTER THREE

TWO HYDROGEN ATOMS IN SPACE

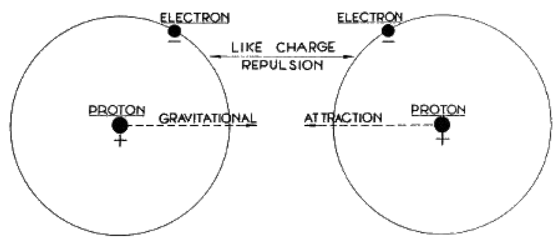
Having examined the individual atom and learned of its characteristics, let us now consider the effect which atoms will have upon each other, when several are in the same vicinity.

We will picture two hydrogen atoms, side by side, but completely alone in space. We will postulate that the atoms are not in motion with respect to each other, and that no fields or other influences are present except those which are produced by the atoms themselves. We will assume that the two atoms are separated by a distance of two diameters. That is: the distance between the orbits of the electrons is equal to twice the diameter of the orbit.

We have learned that the electron consists entirely of a negative charge and that 'like charges tend to repel each other'. Therefore, a force field will be set up which will tend to 'push' the atoms farther apart. We also know, however, that the proton has a gravitational mass, and consequently, a gravitational field will be created which will tend to pull the atoms closer together.

The mass of the proton is more than 1800 times that of the electron, and the gravitational field is considerably more powerful, if measured at the same distance. However, in the case of the two atoms, the effective distance for the gravitational field must be measured between the protons, while the electrical field must be measured between the closest points of the two orbits. (The full charge of the electron must be considered to act simultaneously in all parts of the orbit.)

At this point we must recall the rule first propounded by Sir Isaac Newton, that the amount of force created by a field is in proportion to the inverse square of the distance separating the two points between which the force acts.



In our example, the two atoms are separated by a distance equal to twice their diameter. If we assume that each atom has the same diameter, and if we choose the radius of the atom as a unit of measurement, we find that the protons are separated by a distance equal to 6 radii; while the shells are only 4 radii apart. The distance ratio therefore is 6 to 4.

We will further assume that at this point, the attraction of the gravitational field is greater than the repulsion of the electrical field. The two atoms will, therefore, begin to approach each other, or to 'fall together'. When the shells have reached a distance of one diameter, or two radii, we find that the protons are now four radii apart, or that there is now a distance ratio of 4 to 2. If the atoms continue to approach until the shells are 1 radius apart, the distance between the protons will be three radii, or a ratio of 3 to 1, etc.

We can readily see that, whatever the relative strengths of the two fields to begin with, there will be a distance at which the attraction of the gravitational field will be exactly balanced by the repulsion of the electrical field. We will call this the 'critical distance'. We cannot call it the stable distance because the atoms would not actually stop at this point. In falling together, the atoms would have acquired momentum, and this momentum would carry them inward to a point where the repulsion was greater than the attraction. Then the atoms would

'bounce' apart and because of acquired momentum, would again pass the critical distance in their outward movement. Since the atom may be considered as a perfectly elastic body, and since no friction is involved, this bouncing back and forth, or oscillation, as it is usually called, can and does continue indefinitely, each atom constantly seeking its critical distance, but always being carried beyond it by the momentum of its search.

Even if it were possible to place two atoms exactly at their critical distance without imparting any momentum to them, they would not remain long in that position because there is a factor which almost constantly changes the critical distance between atoms. This factor is known as the photon or quantum of energy.

The word photon is derived from the Greek word 'photos' meaning light. It was chosen because light was the first form of energy which was shown to be composed of definite units.

As our understanding of nature progressed, however, it became apparent that what we call 'light' is simply a form of electromagnetic radiation.

Electromagnetic radiation may be defined as 'Primary energy', since all of the changes which occur in matter come about, either as a direct or as a secondary effect of its action.

This primary energy is divisible into very small, but definite units or particles which have been given the name of 'quanta' in the plural, or 'quantum' in the singular.

The quantum is considered to be an indivisible particle of energy, but one whose energy level is determined by its individual frequency.

The known spectrum of electromagnetic radiation covers a tremendous range of frequencies, from long radio waves on the low end, to high energy cosmic rays, on the other.

Near the center of this spectrum is a narrow band of frequencies, covering about one octave, which we call 'visible light' because radiation of these frequencies can be perceived by the human eye. We divide this band of frequencies into seven narrower bands which we call colors. Starting from the highest frequency and going down, we name these colors violet, indigo, blue, green, yellow, orange and red. All of the hues, shades, and tints of color which the human eye can perceive are created by some combination of these seven frequencies.

It was the quantum, or individual particle of radiation in this particular portion of the frequency spectrum to which the term photon was originally applied. The usage of the term, however, has since been expanded to include a considerably wider band of frequency.

Just below the red of visible light is another, and somewhat wider band which we call infrared. Except for

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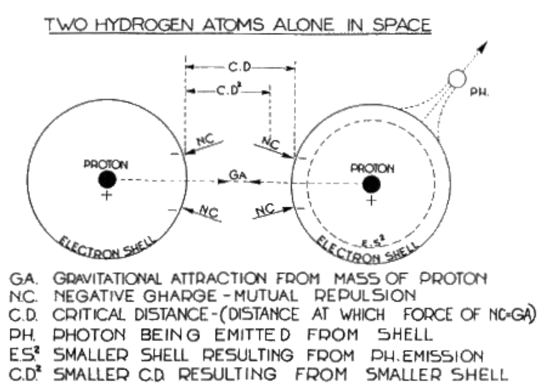
the fact that its frequency is below the range of the human eye, infrared has all of the characteristics of visible light, plus the characteristic that its photons are readily absorbed by the electronic shell of force about an atom.

Each different type of atom, of course, has its own characteristic set of frequencies, and only photons in matching frequency bands will be absorbed. However, most of the photons whose frequency lies within the infrared portion of the spectrum are readily accepted by almost all types of atoms. It is, therefore, with these infrared photons that we are particularly concerned at the moment.

Let us now return for a time to our two hydrogen atoms. We will assume that a photon of infrared radiation,



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emitted perhaps millions of years before from a star millions of light years away in space, strikes the shell of force about one of our two atoms. If the photon is absorbed, the additional energy thus gained, will cause the shell of force to expand. As can be seen by the accompanying diagram, the expansion of the electronic orbit places the electrons closer together than they were before, while the distance between the protons remains the same. If the two atoms had been poised exactly at the critical distance prior to the absorption of the photon, we would now find that a net repulsion existed, and the two atoms would 'bounce' apart seeking the new point of stability, or critical distance where the two fields would again be in balance.

The shell of the atom does not, however, retain these photons indefinitely, but is constantly emitting them. With each emission, of course, the shell becomes one size smaller.

The mean time between successive emissions is determined by two factors, first the nature of the particular atom, and second by the number of photons which are present in the electronic shell. Each time the shell receives a photon it�s diameter increases by a precise amount, and with each emission it shrinks by the same amount.

If the number of photons received within a given time, is greater than the number emitted, the two atoms will constantly tend to move farther apart. If the number emitted is greater, the atoms will tend to move closer

together. If we now learn that the photon of infrared radiation is also known as the unit of radiant hear, we immediately find that we are able to predict one of the fundamental rules of nature, which is that the addition of heat energy to a body of matter will tend to cause that matter to occupy a larger volume of space, or, in simple words, to expand. The loss of heat energy from a body of matter will tend to cause that matter to occupy less space, or to contract. We can make this prediction confidently, even though we may never have heard of this rule or observed it in operation.

A number of other rules of nature may also be predicted through the consideration of the foregoing discussion. Some of these will be mentioned later on in this text.

CHAPTER FOUR

ESCAPE VELOCITY

Let us now assume that each of our two atoms receive a number of photons simultaneously. The orbits of the electrons, in springing outward, would approach very near to each other, and thus produce a very strong repulsion between the atoms. This repulsion would cause an outward movement of the atoms, with a very high rate of acceleration. By the time they had reached their new critical distance, their velocity might be so great that they would continue to move apart indefinitely. As soon as they had passed the critical distance, of course, the repulsion would become an attraction, and the outward motion of the atoms would begin to slow down, As they moved apart, however, because of the increasing distance between the protons, the attraction would also become constantly smaller.

We can see that if the atoms had achieved a sufficiently high original velocity, the attraction would diminish at a greater rate than the velocity, so that there would always

be some outward velocity remaining. The minimum velocity at which this continuous expansion would occur, is known as the 'escape velocity' of the atom.

We have often heard the term, escape velocity, used in connection with the firing of rockets to the moon or to some planet. In this case it is defined as the minimum original velocity which must be imparted to a missile if it is to escape completely, from the gravitational field of the earth. The principle is exactly the same. The gravitational field of the earth exerts a retarding force upon the missile, which constantly slows its outward motion. This retarding force, however, diminishes steadily as the distance from the earth increases, so that if the original velocity is sufficiently high, the retarding force will diminish more rapidly than the velocity, and the missile will continue on and on until it comes into the influence of some other gravitational field and begins to accelerate in that direction.

The velocity of escape from the earth is usually given as being between 7 and 9 miles per second depending upon whether the missile is being fired toward the moon or away from it: whether it is being fired in the direction of the earth's rotation or in the opposite direction: the position of the sun, whose gravitational field produces its own effect upon the trajectory of the missile; and several other minor factors.

In the case of the atom, the velocity of escape depends upon the type and mass of the atom, its temperature, the number and position of other atoms present, etc. It is, however, always a precise velocity for any given type of atom under any given set of conditions.

CHAPTER FIVE

STATISTICAL ACTION

So far, in our examination of the nature of matter, our entire universe has consisted of two lonely hydrogen atoms. By the examination of these two atoms, however, we have learned something of the basic forces which actuate all atoms, whatever their size or number.

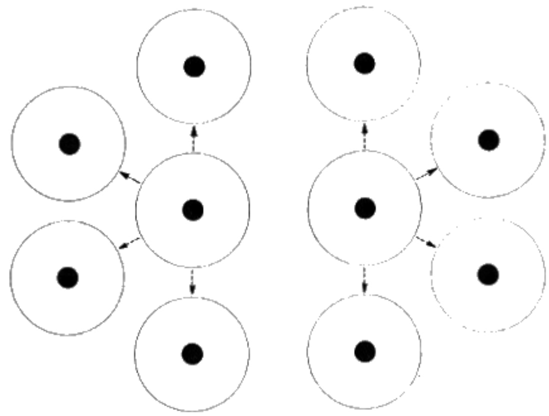
As long as we are dealing with only two interacting atoms, we are observing absolute forces and specific actions which result there from. If we add a large number of other atoms to our original two; as we must if we are to build matter from our atoms, all that we can observe is the statistical result of a large number of forces and actions, each of which is absolute in itself, but contributes only minutely to the resultant action of the whole.

Almost all of our present laws of physics are based upon the observation of the statistical results of a very large number of individual atomic or molecular actions. If we do not understand the individual forces and actions, we have no means of understanding the statistical result of many actions, and so can learn physics only by memorizing

blindly the observed results of certain conditions. It is for this reason that we have spent so much time in observing our two atom universe, but we should now be ready to furnish our lonely atoms with some companions.

If we examine the illustration on the opposite page, we will see that the two atoms with which we have become so familiar, are now surrounded by many other similar atoms. We will assume that our two friends have just absorbed some photons of energy, and are 'bouncing' apart. We can see that before they have gone very far, each of them will intrude upon the critical distance of some other atom, and will bounce from that atom in a direction which will be determined by the angle at which the impact occurred. The atom which was 'struck' would, of course, acquire some of the momentum of the striking atom, and its own path and velocity would be altered accordingly. We could create much the same effect if we were to place a large number of billiard balls upon a billiard table, and rush about it with a cue stick, rapidly striking various balls at random, and in different directions. The balls struck would acquire velocity (kinetic energy), some of which would be transmitted to the first ball which it struck. If we moved fast enough, we would soon have all of the balls in constant motion.

The air friction, the rolling friction on the table, and the fact that the balls are not perfectly elastic, would all rend to slow the balls down. Therefore, if we assume that



our strokes are all of uniform amplitude, the average speed of the balls would be proportionate to the *number of strokes* which we delivered in a *given unit of time*.

In the case of the atoms, the cue strokes are represented by the photons which they absorb. There is no friction, and the atoms can be considered as being perfectly elastic bodies, but the slowing effect is still present because of the fact that the atoms constantly emit photons as well as absorb them.

By comparison with our billiard table experiment, we can see that the *average velocity* of the atoms will be proportionate to the total number of photons per *unit volume*. which are in *circulation* at any given moment.

If two or more atoms have combined to form a molecule, the outer shell of electrons which now encloses all of the atoms, absorbs the photons and produces an effect much the same as in the case of individual atoms.

There are, of course, other means by which the velocity of atoms or molecules may be increased. These means will be considered in the following chapter.

CHAPTER SIX

TEMPERATURE AND HEAT'

The terms 'temperature' and 'heat' are often confused in the mind of the beginning student. In most text hooks on physics the statement is made that the 'temperature' of a body of matter is the measure of the rate of motion of its particles. In simple words, a body of matter is said to be at a high temperature when the atoms or molecules which compose that body are moving at high velocities, and therefore coming into frequent and violent collision with their neighbors. The temperature is said to be low when the particles are moving at low velocities and the collisions are relatively gentle. If the motion should cease entirely, the matter would be said to be at the temperature of absolute zero.

Since all atoms and molecules emit photons so long as any are contained within their electronic orbits, and since the emission or absorption of a single photon will cause oscillation which will ultimately be transmitted to all parts of the matter, it seems obvious that a body of matter can never reach a true state of absolute zero unless

all emittable photons have been lost from the body, and no more are being received from any other source. But as all bodies of matter at temperatures above absolute zero are constantly emitting photons and since these photons travel endlessly through space until they are absorbed by matter, it seems unlikely that any appreciable body of matter has ever reached a true state of absolute zero, although the condition has been approached quite closely in laboratory experiments.

Each atom emits photons at a rate that is proportionate to the total number of photons which it contains. This ratio is the same for all atoms of a given element, but varies with each different type of atom or molecule.

Suppose that we have an atom of hydrogen, and an atom of mercury. Let us assume that the atom of hydrogen emits one photon per second for each ten photons contained in its electron shell. The atom of mercury, on the other hand, emits one photon per second for each two photons contained. We can see that if we added one hundred photons to the atom of mercury, we would increase its emission rate by 50 photons per second, but if we added one hundred photons to the atom of hydrogen we would raise its emission rate by only ten photons per second. We have added exactly the same amount of heat energy to each atom but have raised the emission rate of the mercury atom five times as much as that of hydrogen atom. Since the temperature of a body of matter is proportionate to

the emission rate of its atoms, by adding the same amount of heat to each, we will raise the temperature of the mercury much more than that of the hydrogen.

The total kinetic energy possessed by the particles of a body of matter, is known as the active heat of the body, while the total number of photons still contained within the electron shells of the particles is known as the latent heat of the body. The ratio between the *active* heat and the *total* heat energy of a body of matter is known as the 'Specific' heat of the material of which the body is composed.

The figures which we have given for the emission ratio between hydrogen and mercury, are not, of course, the correct ones. To give precise figures for these two elements we would have to deal in micro seconds instead of seconds, and employ figures with a number of decimal places. We have used simple figures only for the purpose of forming mental pictures of what goes on in, and between, the atoms, in order to gain a better understanding of those often confused terms, 'temperature' and 'heat.

The specific heat of each element is different, and also changes when the elements join to form compounds. That is, when atoms join to form molecules, a change occurs in the amount of heat which must be added in order to raise the temperature to a given degree.

Every element and every compound, however, has a precise ratio of specific heat. Many of these can be found

in any handbook on physics or chemistry. The specific heat of water (H^20) has been chosen as the standard or reference point. It's specific heat is, therefore, said to be 1.000. Since the specific heat of water is high compared to most other compounds or elements, the values of the others are shown as decimal fractions of one.

As we mentioned at the end of the last chapter, the emission or absorption of photons is not the only means of changing the velocity, and therefore the temperature, of atoms or molecules. Obviously, any application of kinetic energy to the particles will have the same effect. Let us imagine that a blacksmith is striking his anvil with a hammer. As the face of the hammer comes in contact with the face of the anvil, the outer layer of particles on the face of the hammer, because of their momentum, will intrude upon the critical distance of the outer layer of particles on the face of the anvil. When the repulsion caused by this intrusion tends to halt the forward motion of the first layer of particles, the second layer, which has equal momentum, will intrude upon the critical distance of the first, the third layer will intrude upon the second, and so on throughout all of the trillions of layers of particles in the hammer. A compression wave will be produced which will race back and forth through both the hammer and the anvil until the linear kinetic energy of the hammer has been converted to a proportionate increase in the random velocity of the particles of both masses. We can

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see that the temperature of the masses would be increased by an amount which is directly proportional to the momentum of the hammer.

If instead of striking the anvil, we were to rub the face of the hammer against the anvil the same effect would he created. Since the surfaces are not perfectly smooth, projections from one surface would interlock with projections from the other. Large numbers of particles would be forced from their normal positions. Some of these would snap back into place when the opposing projection had passed, and some would be torn away entirely. In either case however, the temperature of the mass would he increased by an amount which was proportionate to the force applied to the hammer, and the distance which it was moved.

The striking of the anvil would be described as 'work by impact' while the rubbing action would be described as 'work by friction.'

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CHAPTER SEVEN

SOLIDS; LIQUIDS AND GASES

Before going farther in our study of the phenomenon which we call heat, it might be well to consider briefly, the three states of matter which result from the various degrees of heat energy or temperature which the matter may possess at a given time.

Let us consider first, a quantity, or block of atoms or molecules in which the total number of photons contained is small. The orbits of the electrons, and therefore the size of the atom is also small. The oscillation or 'bouncing' of each atom will continue, but the path of each bounce will be small because the atoms or molecules are quite close together, and their critical distance is small. Since none of the particles reach escape velocity, each particle will remain in the same relative position with respect to the others. The mass will retain its shape indefinitely, and a considerable amount of outside force would have to be applied to cause the body to change in shape. This condition is known as the solid state of matter.

If, to such a block of matter, we suddenly added a

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large quantity of energy in the form of photons, the orbits of the atoms would spring outward, the velocity of their oscillation would increase tremendously, and soon every particle would acquire a velocity greater than is escape velocity. The particles in the interior of the mass could not immediately escape because they would still be bouncing about among their neighbors, but the field of each particle would now be repelling all of its neighbors, and the mass would expand rapidly. The particles on the outside of the mass would move outward indefinitely, leaving the next layer free to escape, and so on. Matter in this condition is known as 'gas.'

Specifically, a gas is defined as being a body of matter in which all, or virtually all of its particles have velocities in excess of the escape velocity for the particular conditions in which they exist.

We can readily see that a gas, if released in a vacuum, will expand indefinitely, and if released within a solid container will expand until it is uniformly distributed throughout the volume of the container. Each atom or molecule, upon colliding with another, will glance off in a new direction, and will continue in that direction until another collision occurs.

The average, or 'mean' distance which a particle travels between such collisions is known as 'the mean free

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path.' In a dense, or 'compressed' gas the mean free path would be a very tiny fraction of an inch, but in a very ratified gas, it might be many feet.

The liquid state of matter is not, in the strictest sense of the word, a true state of matter at all because it is dependent almost entirely upon exterior influences, such as the earth's gravitational field, its atmospheric pressure, etc. If we were to take a sample of almost any liquid to a remote point in space where there were no gravitational fields or atmosphere to affect the sample we would find that, even though we maintained the temperature at the same level, the liquid would have the characteristics either of a soft solid or of a gas.

A liquid can be defined as a body of matter whose particles have velocities either slightly below or slightly above their natural escape velocity. Most oils or liquid metals, for instance, can be described as matter whose particle velocities are so close to that of escape that the additional force applied by a gravitational field such as that of the earth is sufficient to cause the particles to escape, or 'flow' in the direction of the force applied by the field. If such matter were removed from the influence of exterior fields, and released in space, it would immediately assume the shape of a sphere, which shape it would retain indefinitely so long as no exterior force were brought to bear. It would, therefore have the characteristics of a very soft solid.

A glass of ordinary water, on the other hand, has the characteristics of a gas, which is prevented from expanding by the pressure of the atmosphere around it.

We can demonstrate this if we take a glass of water which is at, say 100°F, place it in a bell jar, and suddenly remove the air from the jar. The water will immediately begin to boil quite briskly. If we maintain the temperature of the water at 100° and pump out the gas as it is formed, the glass will soon be empty, demonstrating that its particles do have velocities above those necessary for escape. Actually, even though we do not remove the air, molecules of the water will constantly be escaping from the surface in spire of the downward bombardment of the air molecules, and the glass would eventually become empty. This, much slower process of escape by the mingling of the molecules of a liquid with the molecules of a surrounding gas is known as evaporation.

CHAPTER EIGHT

HEAT TRANSFER

In any standard text book on physics, three methods of heat transfer are usually discussed. These three types of heat movement are known as, conduction, convection, and radiation. Conduction is defined as being the transfer of heat energy from particle to particle in a solid substance. Convection refers to the transmission of heat, usually in a gas or liquid, where the heat is carried from one point to another by the motion of the gas or liquid which contains it.

Radiation, of course, refers to the transmission of heat by the emission of photons, or quanta of heat energy. In order to gain a simple understanding of heat transfer from the nuclear standpoint, let us perform an imaginary experiment, in which all three of these types of transfer will take place.

We will clamp a bar of iron in a machinist's vise, and to the upper end of the bar, we will apply the flame of an oxy-hydrogen torch.

When two atoms of hydrogen combine with an atom of oxygen, a molecule of ordinary water is formed, but the joining of the atoms causes a large number of the photons of energy contained in the atoms, to be emitted almost instantaneously. The water which is formed, instead of appearing as a liquid, becomes a gas at a tremendously high temperature. The gas is emitting large numbers of heat quanta, and also a few of the higher frequency photons which we call light.

The heat quanta, striking and being absorbed by the atoms of iron in the bar, cause a great increase in the velocity of their motion. The molecules of the gas, of course, have velocities far above that of escape, and as these molecules strike the particles of iron, a large percentage of their kinetic energy is transmitted mechanically, just as the motion was transmitted by the balls in our billiard table experiment. The energy which is transmitted from particle to particle within the bar itself, is known as conducted heat.

Since the incandescent gas is moving from the point of combustion at the tip of the torch, to the surface of the iron, its motion is carrying its supply of kinetic energy to the surface of the iron. This process is described as 'convection' because the heat is being 'conveyed' from one point to another by the motion of the gas which contains it.

The photons of infrared energy which are emitted at

the point of combustion, do not, of course, follow the flow of gas, but radiate in all directions at the velocity of light until they strike and are absorbed by the iron, or some other body of matter. This type of heat transfer is, therefore, known as 'radiation.'

The iron bar, while it is receiving a very large flow of photons from the gas, is also, at the same time, emitting a smaller number. We can demonstrate this by continuing to direct the flame upon the surface of the bar. As the temperature of the iron rises, the frequency of the photons which it emits will also increase until finally some of the photons will have frequencies in the lower part of the visible spectrum, and we say that the bar is becoming 'red hot.' If we add still more heat, the frequency of the emitted photons will continue to increase and we will see that the bar has become white hot.

The iron particles are now approaching their escape velocity. If we continue to add heat, we will soon find that the force of the earth's gravity will be sufficient to cause those particles, which are moving in the direction of its attraction, to move beyond their normal range. The mass will begin to move, or 'flow' in the direction of the gravitational attraction. When this occurs, we say that the iron has 'melted.'

Having observed the transfer of heat from a gas to a solid, by hearing the gas, let us see if we can raise the temperature of a gas without adding any heat.

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We will imagine a simple steel cylinder, closed on one end, and with a closely fitting piston in the other. Through a small hole in the closed end we will insert the bulb of an ordinary mercury thermometer, sealing it so that no gas can escape from the cylinder. If we allow this apparatus to rest quietly upon a table in our laboratory, and maintain a constant air temperature in the room we will find that the air inside the cylinder, the air outside the cylinder, and the material of the cylinder itself will soon reach the same temperature. If we now suddenly push the piston halfway down in the cylinder, so that the gas within is compressed to half of its original volume, we will find that the temperature of that gas has risen sharply. The total number of photons in circulation has not increased, but because the volume has been reduced, more photons are in circulation per unit volume. This means, of course, that the walls of the cylinder, which are in contact with the gas, will receive more photons, per unit area, than they were receiving before the gas was compressed. The walls of the cylinder are, therefore, receiving heat energy from the gas.

The total kinetic energy of the gas within the cylinder also remains the same, but because of the compression, the mean free path of the particles is shortened. Collisions become more frequent and more violent. This increase of oscillation rate is also transmitted to the walls of the cylinder.

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Since the bulb of the mercury thermometer, which we inserted into the cylinder, is surrounded by the compressed gas, a proportionate amount of the energy will be conducted to the mercury in the bulb, causing it to expand. By observing the amount of expansion of the mercury, we can treasure the rise in temperature caused by the compression of the gas.

The extra heat absorbed by the walls of the cylinder will gradually be passed along to the air outside, until the gas inside has reached its original temperature. It now, however, contains less heat than it had before. By compressing the gas, we have literally 'squeezed' some of the heat out of it.

If we now draw the piston out to its original position, the gas will expand to fill its original volume. The mean free path of the particles will be lengthened, the collisions will be fewer, and the number of photons emitted, per unit area will be smaller than the number which the gas received from the walls of the cylinder. In other words, its temperature has gone down, and the gas is now taking back from the cylinder, the heat which it gave up when it was compressed. A proportionate amount of heat will, of course, also be taken from the bulb of the thermometer, causing the mercury to contract, and thus to indicate the lower temperature.

Almost all of the commercial and household refrigeration systems in use today are based upon the principle of

compressing a gas in one part of the system, dissipating the heat released at that point, and then allowing the gas to expand in another part of the system, so that it will continuously take up heat from that part.

CHAPTER NINE

PRESSURE

In our experiment with the cylinder and the piston, we discovered that a considerable amount of force was required to push the piston into the cylinder. Much more than that would be required to overcome the friction between the piston and the cylinder. We also noted that as long as the gas was compressed, a force continued to act upon the piston, tending to push it back out to its original position. We can readily understand why this should be so. In fact, even our brief consideration of the actions of gas particles had enabled us to predict that it would be true, even before we performed the experiment.

When the surface of a solid is in contact with a gas, the particles of the gas because they are moving at random in all directions, are constantly impacting, or beating upon the particles of the solid. The millions of tiny impacts which occur each second, produce a constant thrust or force upon the surface of the solid. We call this force 'the pressure' of the gas.

We can see, at once, that the amount of this pressure, upon a given area will be determined by three factors. First, the number of particles which strike the given area in a given time. Second, the velocity of the striking particles. Third, the mass of the striking particles. We can also see that the number of particles which will strike a given area in a given time will be determined by the number of particles contained within a given volume of the gas, and upon the rapidity with which they oscillate.

These facts bring out the close relationship which exists between temperature and pressure in a gas.

Stated as briefly as possible, the temperature is the measure of the total kinetic energy present, per unit volume, while the pressure is the force which that kinetic energy exerts, per unit area, upon any restraining surface. For example, the air which we breathe is a gas composed principally of two elements, oxygen and nitrogen. Bur for two preventative factors, all of the earth's atmosphere would long since have been diffused into space. The first factor is the earth's gravitational field, which constantly tends to draw all of the particles back to the surface. The second is the fact that the particles at the outer edge have lower temperatures and therefore lower velocities than those near the surface.

If we assume that we are at sea level, and that the temperature of the air is 0° centigrade (32°F) the number of particles in each cubic inch of space will be about 400 quintillion. (400, million, million, million.) The

average velocity of the particles will be about 1,760 feet per second, or twenty miles per minute. This velocity becomes even more remarkable when we realize that the average distance which any of these particles can travel before colliding with another is only about four millionths of an inch. This means that each particle undergoes an average of more than five billion collisions per second. The kinetic energy of these collisions is sufficient to produce a constant force of 14.7 pounds upon each square inch of surface which receives these impacts. This is why we say that the air pressure at sea level is equal to 14.7 pounds per square inch.

We can readily see that the individual forces and masses of atomic or nuclear particles are exceedingly small when compared to our usual standards of measurement. Most of the quantities with which we must deal in the study of nuclear physics are so infinitesimal in comparison with our everyday standards, that it has been necessary to create new and much smaller units of measure in order to deal readily with these minute quantities.

Since these standards of measure may readily be found in any text book, we have not dealt with them here. We have considered the photon, the neutron and the electron without determining their size or mass. We have discussed the constant rapid motion of the atom without measuring the velocity of the particles, the length and their mean free path, or the frequency of collision (except

for the one example, air, which we have just considered.) All of these quantities are listed in handbooks, created for the engineer or the physicist who must obtain specific answers to specific problems. In this text we are primarily concerned with bringing about a supple understanding of the significance of these factors, and the conditions which cause them to exist.

The reader who has perused these pages carefully and diligently, will already have achieved a degree of understanding sufficient to enable him to predict most of the laws of thermodynamics, which fill hundreds of pages in present day text books.

We will therefore take leave of our particles for a time in order to consider a few of the least understood factors of nature, gravity, space and time.

CHAPTER TEN

THE NON LINEARITY OF PHYSICAL LAW

For several thousands of years, the more advanced thinkers among the races of earth, have dreamed of the day when earthmen would succeed in breaking the bonds of his terrestrial prison, to soar freely out into space, and to explore at will, the utmost depths of a boundless universe. To most men, however, the dream had seemed to be one that was impossible of fulfillment.

Now we are suddenly awaking to the fact that the dream is becoming a reality, that this generation is going out into space.

The author has stated, in a number of recent lectures, his opinion that some of the young men who are now in their first or second year of high school, will stand upon the surface of Mars or Venus before they reach their thirtieth birthday. While this prediction may appear to be over optimistic to most readers, it is nevertheless a fact, that the development of the physical science progresses at a rate which constantly amazes, even those who are foremost in its pursuit.

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Man's attempt to escape from the rather irksome confines of his tiny planet, has always been hampered by his lack of understanding of four of the primary factors of the universe: Gravity, Space, Time and Energy. It has always seemed that there was too much of gravity and space, and not enough of energy or time. About the year nineteen hundred and five, however, it was brought to man's attention that these factors were not the absolute and independent entities that he had always considered them to be, but that they were variable factors, each having a value which depended upon the value of others. Thus the first faint light of understanding began to filter through the dense screen of absolute determinism which had been erected about the physical science.

Unfortunately, our men of science, instead of pursuing this bright gleam of truth, attempted, from force of habit, to mould it into the common pattern of knowledge, by reducing it to a mathematical formula, which could be used without the necessity of understanding it.

The series of mathematical formulae which Albert Einstein gave to the world in 1905, he called "A Theory of Special Relativity." We have attempted to make of it a 'universal law of absolutes'.

We have ignored the foreword with which he prefaced the mathematics, and so have created the very thought blocks which he had hoped to prevent.

We will refer to this problem later on, but it might

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be wise first, to devote a little time to the consideration of what we will call 'the non linearity of physical law.' Until a few decades ago the physical laws which govern the universe were considered to be linear. That is: we had, by trial and error, by observation and test, developed a set of laws which apparently held true for all of the small segment of nature which we were able to observe at the time. We assumed therefore that these laws would hold true in any segment of nature, no matter how far removed from our point of observation. When, however, the study of physics moved into the microcosm, that is, when we began to examine the interior of the atom, we found that we were dealing with laws which did not agree with those to which we had been accustomed. These laws too appeared to be linear but followed a different ratio of response. The same disturbing situation was discovered in our examination of the macrocosm. When our astronomers developed the giant telescope capable of peering many millions of light years into space, they found that here too, the physical laws appeared to undergo a definite change.

For a time we attempted to accustom ourselves to the existence of three sets of physical laws, each set linear within its own range of observation, but having different fundamental characteristics. Then with the development of the principles of relativity, we began to understand; or at least, we should have understood, that these

different sets of linear laws, were not actually linear, nor were they different sets of laws. They were simply three widely separated segments of the one great curve of natural law.

As long as we were dealing with quantities which could be observed with the unaided eye, or with simple instruments we were unable to detect the curvature, because the segment which we were observing constituted such a tiny portion of the curve that its deviation from linearity was too slight to be detected.

For most practical purposes connected with the ordinary mechanics of our daily lives, these laws are still considered to be linear. Calculations are simpler when they are so considered, and the resulting error is negligible. For the same reason, a surveyor who is surveying a small residence lot, does not find it necessary to take into consideration the curvature of the earth, because the error resulting from this neglect has no significant effect upon the placing of his stakes. If, however, the surveyor is to make accurate measurements of large areas such as a state or continent, it does become imperative to consider the curvature of the earth's surface, and to do this, of course, it is necessary to have a reasonably accurate knowledge of the radius of that curvature.

The necessity of an accurate determination of the radius of curvature of natural law was first realized perhaps, by Dr. Albert Einstein, who devoted a large part

of his life and his work to this problem. The results which he obtained have filled a number of textbooks, and have proved to be of inestimable value in the progress of the physical science. They pointed the way to the utilization of nuclear energy, and have many other implications which are sensed, but are not yet completely understood.

The difficulty with our present mathematical approach to the problems of relativity lies not in any error of the mathematics themselves, but in the fact that the methods and terms used in the attempt to explain them often lead to incorrect thinking and assumptions.

In the theories of relativity given to the world by Dr. Einstein, the natural laws, in general, are assumed to be linear, but the space in which they operate is considered to be 'curved.' This concept offers the simplest mathematical presentation, since all of the deviations from linearity can thus be explained by a single postulate. Unfortunately, like most of our mathematical presentations, the concept offers but little for the mind to grasp. A curved space cannot be pictured mentally, nor can it be drawn upon paper. The question always arises, if space is inside the curve, what is outside?

We have discovered that the linear mathematics which we commonly apply to the 'laws' or rules of nature, do not hold true when carried to an extent which permits the error to be measured, because they do not

follow a straight line reaching to infinity, but a curve of finite radii. In a timeless universe, this curve, in any given plane, would be represented by a circle, but since the laws operate through time as well as space, the curve may be more readily understood if represented by a 'sine curve' or 'wave.' The 'base' (which is the center line of the curve) represents zero, while the portions above and below the zero line represent the positive and negative aspects of the law.

Thus we see that there are positions and conditions in which the effect of a natural law will reach zero value with respect to a given reference point, and that beyond these positions and conditions, the law will become negative, reversing its effect with respect to the observer. (The constant repetition of the term 'reference point' or 'observer' is necessary to emphasize the frequently forgotten fact that none of the basic factors of nature have any reality or significance except when considered from a specified position, or condition.)

If, therefore, we exchange the existing mathematical postulate of *linear laws* operating in a *curved* space, for a concept based upon the curvature of natural law, we will find that we have not invalidated or changed any of the presently accepted mathematics which we apply to these concepts. They can still be applied in the same way, and will give the same results.

By the exchange, however, we will have achieved a position from which the operation of the natural laws can be pictured by the mind, and can be charted upon paper. Thus we will have taken a great step in the direction of understanding.

CHAPTER ELEVEN

GRAVITY

Perhaps the greatest obstacle to man's achievement of his dream of space travel has been a factor which has been given the name of Gravity. Its 'discovery' is usually credited, in elementary school text books, to a seventeenth century mathematician and physicist, Sir Isaac Newton. Actually, of course, every man 'discovers' gravity soon after birth; and the stone age man who first rolled a boulder down upon the head of the cave bear who was attempting to scramble up the cliff after him, was making a practical application of this force. It was, however, Sir Isaac Newton who first made a complete mathematical analysis of the subject. His conclusions were compatible with subsequent observation and test, and were virtually unchallenged until the dawn of the era of relativity.

In brief, his conclusions were that gravity is a quality which is inherent in all matter, and that it manifests itself as a mutual attraction between all bodies of matter. The value of this attraction between any two given bodies was said to be directly proportionate to the

product of their mass and inversely proportionate to the square of the distance between them.

The attraction between the earth and an object near its surface is an example of this force, although it is usually described as being the 'weight' of the object.

The difficulty with the statement that the force varies inversely as the square of the distance lies in the implication that if the distance becomes zero, the force should become infinite. Thus it would at first seem that a man standing or lying upon the surface of the earth would be one of two bodies between which the distance was zero, therefore, the weight of the man should be infinitely great. The reply to this assumption is that the force acts as though it originated at the center of the mass, called the 'center of gravity, and that the man on the surface of the earth is still some four thousand miles from its center of gravity. This explanation, however, creates a new problem in that, if we accept it literally, we must assume that if there were a well or shaft extending to the center of the earth, and if a man descended this shaft, his weight would increase as he approached the center of gravity, becoming infinite as he reached it. Actually, of course, his weight would decrease, becoming zero when his center of gravity coincided with that of the earth. So we are forced to the further explanation that gravity is inherent, not in 'bodies', but in particles of matter, and since a man at the center of the earth would

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have an equal number of particles attracting him from every direction, the resultant of the forces would be zero. If we assume the gravity to reside independently within each atom, our problem is solved as far as the man and the earth are concerned, but if we look within the atom itself in the attempt to find the point where the distance becomes zero, and the force infinite, we find that the same problem again confronts us. We have not solved it, we have only changed our scale of observation. There is conclusive evidence that the attraction, called the binding energy, which exists between the Newtonian particles, (the protons and the neutrons) is intense almost beyond our ability to describe. This force, however, does not increase uniformly with increasing mass, but at certain points not only reaches zero but actually becomes negative.

We can demonstrate this fact by adding a single unit of Newtonian mass, a neutron, to the nucleus of an atom of Uranium 235. When this is done, we find that the gravitational force within the nucleus, instead of increasing becomes negative, that is, the attraction between its parts becomes a repulsion, and the parts begin to separate with considerable brisance. During the expansion, however, several new centers of gravity are formed, which, because of the smaller amount of mass involved in each, are strongly positive. The result is that two or more simpler atoms are formed.

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In most text books, this phenomenon is described as the 'splitting' of the atom. There is an implication that it is the 'impact, or the kinetic energy of the neutron which causes the atom to split. If this were true, then obviously, a high speed neutron would split the atom more easily and surely than one with much lower speed. Actually, the opposite situation is true. The high speed neutron will not split the uranium atom at all. It must be slowed to thermal velocity so that it can settle into the nucleus before fission occurs.

Occasionally a neutron will be captured by a uranium atom, without falling directly into the nucleus. The neutron may orbit the nucleus for a very long time (as time is counted in nuclear physics), perhaps several seconds or even minutes. Eventually the neutron drops into the nucleus, and 'delayed fission' occurs, again demonstrating the fact that it is not the impact of the neutron, but its presence in the nucleus, which results in its expansion.

The expansion and subsequent condensation into several simpler atoms is a completely random process. Many simpler types of atom can, and do result from the condensation, in each case however, the smaller atoms cannot contain as many neutrons in proportion to the number of protons as the larger atom, so there are always several neutrons left over.

This phenomenon, if carefully examined and considered, will furnish several strong clues to the nature of

gravity itself, but let us for the moment, content ourselves with the observation that it demonstrates that a gravitational field can, under certain conditions, become negative.

Because of the manner in which our gravitational laws have been expressed, it has commonly been assumed that a gravitational force can manifest itself only as an attraction between two bodies of matter. This is not, however, a necessity of thought, since there is no logical reason why it should necessarily be true. In fact if it were true, it would set gravitational fields apart as the only force fields with which we are familiar which could not produce a repulsion, as well as an attraction between bodies of matter. The reason for the assumption of a universal attraction is simply that all of our early and limited observations seemed to indicate that this was true. However, as we have already mentioned, any number of observations, if made on a sufficiently limited scale, will tend to indicate that the earth is flat, rather than spherical.

For many years a school of thought existed which recognized that gravitational fields, like all other fields, must possess a dual polarity. They called these poles, gravity and levity. They assumed that some objects and materials normally possessed the quality of gravity, while others normally possessed the quality of levity. An object possessing levity would be repelled by all objects possessing gravity. The theory eventually became discredited, and was almost universally discarded, not because it was ever disproved,

but because so many attempts had been made to assign this quality of levity to objects and materials which did not actually possess it. For instance it was, for a time, assumed that gases such as hydrogen and helium possessed levity because when they were contained in a light bag or envelope, they were observed to rise against the gravitational field. It was soon demonstrated, however, that their rise was not caused by any quality of levity, but simply because their specific gravity was less than that of the air they displaced. After a number of unsuccessful attempts to assign the quality of levity to specific materials and objects, the theory fell into disrepute to the extent that the very word levity has become synonymous with humorous nonsense. Nevertheless, the philosophers who developed the theory were perfectly correct in their primary postulate. They erred only in failing to realize that gravity and levity are not properties of specific materials but are conditions under which all matter may come.

We have now observed negative gravitation in the microcosm (the interior of the atom), we also observe it in the macrocosm (between the galaxies).

Many technical articles have been written in recent years concerning "Our Expanding Universe," yet where, in any of them, can we find any logical explanation or reason why it should expand at all? Under the theory of universal attraction, all of the matter in the universe should be rapidly coalescing into one gigantic lump. Instead,

we find that every one of the large groups of stars which we call 'galaxies' or 'galactic clusters' are retreating from every other group, at velocities which increase with their distance from the observer. Velocities of recession approaching that of light have been calculated for those which are most distant from us.

A number of interesting but hardly convincing theories have been advanced in the attempt to reconcile the observed state of the universe with the existing concept of universal attraction. Some of our cosmic theorists have proposed that at one time all of the matter in the universe was contained in a single tremendous star, or 'atom'. For some reason, which is not given, this atom exploded, hurling outward the matter which has become the star clusters, and imparting to them the motion which we now observe, several billions of years later. This theory, first propounded by Abbe Lemaitre, has become known in colloquial parlance, as "The big bang theory." It was popular for a time, but as knowledge of the size and nature of the universe increased, it became obvious that such a theory would not stand up if examined under the existing concept of linear natural laws.

In the first place, such an inconceivably huge mass of matter, even at the very great temperature which was assumed for it, would, under Newtonian laws, produce a gravitational field so intense that no velocity less than that of light itself would be an 'escape' velocity. In fact it has

been calculated that even the light emitted by this huge sun would not escape completely, but would circle in a comparatively small orbit around it. Through the concept of the curvature of physical law, however, we see that the addition of mass to an existing body does not, necessarily, increase the force of attraction between its parts, but may, under certain conditions, cause the field to become negative, and the attraction to become a repulsion. We can explain the observed actions of the present universe by postulating that an attraction exists between the individual bodies within a galaxy, because their total mass and distance is such that they are within the positive portion of the gravitational curve with respect to each other. In the vast spaces between the galaxies however, the curve dips below the zero line, with the result that a repulsion exists between

In July 1958, Parry Moon, of the Massachusetts Institute of Technology, and Domina Eberle Spencer of the University of Connecticut, published an excellent paper in the Journal of the Franklin Institute, titled "The Cosmological Principle and the Cosmological Constant." This paper demonstrates, logically and mathematically, that the assumption of a positive gravitational force within galaxies or galactic clusters, and a negative gravitational force between the clusters, offers the only practical means of explaining the observed actions of these bodies.

In the January 1959 issue of the magazine "Astronautics', Fritz Zwicky of the California Institute of Technology, published an article headed, Is Newton's Law of Gravitation Really Universal?" In this article Zwicky pointed out that present observations indicate rather conclusively that the gravitational fields of the galactic clusters reach zero value between the dusters.

the galaxies themselves. This also explains why matter, although rather evenly distributed throughout the known universe, is not distributed uniformly, but is found in quite similar concentrations at comparatively regular distances.

At this point we hear someone say, "These explanations may be very interesting to the astronomer or to the theoretical physicist, but how can they help us in achieving space travel?" The answer is, of course, that we trust have some understanding of the physical laws before we can make the proper use of them in attaining our own personal ambitions.

In his dream of space travel, man has generally considered only three possibilities of escaping from the earth. First, gravity must be destroyed. That is, the operation of the gravitational field must cease between the space craft and the earth, so that it will not hinder the departure of the craft. While a number of highly imaginative stories have been written along this line of thought, no theory has ever been evolved, or test conducted which could give us any hope that such a condition can be achieved.

Despairing of the first possibility, we pass on to the second. Gravity must be shielded. Some type of screening material must be interposed between the craft and the earth to cut off or absorb the gravitational field so that while it still exists, it will no longer act upon the craft.

here again we have found imagination raising our hopes, and reality disappointing, for no material has been discovered which shows any promise of fulfilling such a function. With our hopes considerably subdued, we pass on to the third possibility. Gravity must be overcome. We must apply a greater force, so that we can rise against the pull of gravity, even though we must pay an exorbitant tribute of energy for each foot of progress. In this last plan, we have achieved a certain degree of success. Instrument packages have been placed in orbit about the earth, one has been dispatched to the moon, and several have been placed in independent orbits about the sun.

It does not appear however, that the proper solution has yet been achieved.

When man attempts to attain his ends by pitting one natural law against another, he usually finds that it is a wasteful and laborious process. While it is true that it is perfectly possible to propel a rowboat by throwing rocks from the stern, it is not a method which an intelligent man would choose if he were aware of other possibilities. In the first place, the thrown rock must accelerate, not only the boat, bur all the rocks which remain to be thrown. If a long journey were planned, the greatest problem would be to find enough room in the boat to store the required number of rocks. Since the thrust produced is equal to the mass of the rock multiplied by the velocity of its ejection, it is obvious that there are three limiting factors.

First, there is the total mass of the available rocks, which is limited by the size of the boat which contains them. Second, there is the total amount of energy available. (This is a factor only because we have so little understanding of the true nature of energy.) The third, and at the present time the most serious factor, is the limited mechanical strength of the throwing arm.

In a rocket motor, the 'rocks' are represented by a gas produced by combining or 'burning' the fuels within the combustion chamber, the gas, at a high temperature and pressure, is expelled through an opening or 'venturi' in the stern. Since the amount of fuel is limited by the size of the rocket, the only means of increasing the total thrust is to increase the velocity of ejection, but this can only be accomplished by increasing the temperature and pressure of the gas within the combustion chamber. Regardless of the amount of energy which is available, the amount of thrust which can be produced is limited by the ability of the chamber to withstand the temperatures and pressures involved. Since these limits are reached (and often exceeded) by ordinary chemical energies, it is clear that the vastly greater energies available in nuclear reactions, are, at the present time at least, of academic interest only to the rocker engineer. In the case of craft which remained in our atmosphere, of course, more 'rocks' could be taken aboard while in flight, by scooping up the atmosphere through which the ship was traveling, and allowing the surplus

energy to act upon it. In space flight, however, this is not practical.

Attempts are being made to overcome this problem through the concepts of the "Ionic" or the 'Photonic' drive, in which ions or photons are used as the 'rocks' to be thrown overboard. Ions and photons have a basic advantage over atoms or molecules in that they achieve much higher velocities without the necessity of high temperatures or pressure.

There are, however, great obstacles to the embodiment of these concepts in practical devices, and it appears unlikely that either will lead to economical space travel in the near future.

It is time to re-examine our position to see if there is not something we have overlooked. Have we forgotten the old saying, "If you can't lick 'em join 'em?"

We have tried for centuries to 'lick' the force of gravity. We have tried to destroy it, and failed. We have searched for some method of shielding ourselves from its effect. We have not discovered it. We have attempted to overcome it by opposing it with superior force, and found it a wasteful and cumbersome process. Isn't it about time we gave up the idea of fighting the force of gravity, and began to consider the possibilities of making use of it?

We have learned that gravity, like all natural factors, has a negative, as well as a positive value. If after building our space craft, we could arrange conditions so that the ship was in the negative portion of the gravitational curve, it would fall away from the earth as easily and as naturally as a stone dropped from a tower falls toward the earth.

Of course, we hear at once the objection that, while negative gravitational fields have been shown to exist, they have been found only within the atom and at inter-galactic distances. How can we place a space ship within the negative portion of the curve, with respect to the earth? The answer to this question lies in the fact that, as we have already learned, the natural laws are not absolute, but relative. That is, the size and shape of the curve of one law is dependent upon the value and position of the others. We have seen that the nucleus of the atom of uranium 235 dips below the zero line with the addition of only one mass unit, making a total of 236, yet the nucleus of the atom of uranium 238, although close to the zero line is still on the positive side of the curve because of the fact that the shape of the gravitational curve is modified not only by the mass present but also by the number and position of the electrical charges.

When we acquire a better understanding of the laws, we will be able to produce any shape of curve we desire, with the earth as one reference point and the spacecraft as the other.

Suppose you were to hand a bar magnet and a similar bar of soft iron to a man who was intelligent, but uneducated, with the request that he examine and test the two

objects in order to determine their properties. One of the properties which the researcher would be certain to list would be the 'inherent' property of mutual attraction between the two objects. He would observe that when either end of one bar approached either end of the other bar, a condition of attraction was observed. He would probably conclude that the attraction was an inherent quality of these objects, and that it would continue to persist regard-less of anything which could be done.

We know, of course, that if a length of insulated wire were wound around the soft iron bar, and a flow of electrons were induced in the winding, the two bars could be made to exhibit a repulsion as readily as an attraction. Note that in this case we have not destroyed the field of permanent magnet, we have not shielded the field, nor have we overcome it. We have simply produced a field which is in opposition to it, and the two objects now tend to separate rather than to come together.

The same possibility exists with respect to gravitational fields. While the results will probably not be achieved in the same way, it should not be too difficult to work out means of polarizing a gravitational field, once we discard the old assumption that it is impossible.

CHAPTER TWELVE

MATTER AND MASS

Much of the confusion which exists in our scientific concepts today is brought about by our failure to distinguish carefully between matter and mass. Until a comparatively few years ago, it was assumed that mass was a property which was exhibited only by matter. Upon closer examination, however, it appeared that energy also possessed mass, since when energy was added to a body of matter, the mass of the body was increased.

We have defined mass as being resistance to change in the existing state of motion. It is measured by the amount of the energy which is required to produce a given change in velocity. All matter has the property of mass, but not all mass has the properties of matter. For the purposes of this discussion, we will postulate that there are two types of mass, inertial mass, which is simply the property of resistance to change in a state of motion, and the mass inherent in matter, which we will call Newtonian mass, because it includes all mass which obeys the original laws laid down by Sir Isaac Newton. Since the reader may

be under the impression that all mass obeys the Newtonian laws, let us pause here long enough to examine the facts and to point out the differences in the properties of inertial and Newtonian mass.

All physicists of today are agreed that the electron has mass. Yet if it were possible for us to hold an electron between two of our fingers and then suddenly release it, we would find that there was not the slightest tendency for the electron to fall to the earth (unless the surface happened to be positively charged at the moment). The electron is nor in the least affected by the gravitational field of the earth, so long as it is at rest with respect to that field (if the electron is moving through the field, however, the direction of the motion will be affected).

The electron has mass only because it has an electric charge. As we know, when an electric charge is accelerated in space, a magnetic field is produced, and energy is required to produce this field. The energy 'spent in producing this field, is said to be the 'mass' of the electron, since it is the entire cause of its resistance to acceleration. The greater the degree of acceleration, of course, the more intense the field, and the greater the amount of energy required to produce it. So we say that the electron gains 'mass' with every increase in its velocity. If an electron could be accelerated to the velocity C (commonly called the velocity of light), it would have acquired the maximum velocity with which energy can be propagated.

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It is obvious, therefore, that no amount of energy could further accelerate this electron (with respect to its original reference point), so it would be considered to have acquired 'infinite' mass.

Let us take time to examine this statement carefully, since it is a point upon which there is much confusion. The electron would have acquired infinite mass only in reference to its original energy level. If observed from a reference point which had itself received the same degree of acceleration, the mass of the electron would not have changed a particle. This increase of inertial mass with increasing velocity, is simply the measure of the kinetic energy differential between the observer and the point which he is observing.

We will attempt a simple analogy, in the hope of making this more readily understood. An observer is stationed in 'free space' far from any gravitational or other fields which might affect the results of the experiment which he proposes to make. He has, in one hand, a sphere of cork or other light material which has a mass of 10 grams. In the other hand he has a pistol which fires bullets also having a mass of 10 grams and a velocity of 1000 feet per second. The man holds the ball out at arms length, and fires a bullet from the gun into it. We will postulate that the bullet is not absorbed by the cork, but shares its kinetic energy with it, so that after the impact, the bullet and the cork ball each have a velocity

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of 500 feet per second. The observer now fires a second bullet at the cork. This bullet also has a velocity of 1000 feet per second with respect to the observer, but now the target has a velocity of 500 feet per second in the same direction, so that there is a differential of only 500 feet per second which the bullet can share with its target. After this impact, the bullet and the ball each have a velocity of 750 feet per second. When the observer fires the third bullet, he finds that now there is a differential of only 250 feet per second between it and the target, so that the velocity of the target is raised by only 125 feet per second, and so on.

The observer notes that each succeeding bullet, although it has the same energy with respect to him, produces a smaller and smaller acceleration in the target. He would observe that the 'mass of the target' (its resistance to acceleration) appears to increase with its velocity. If he made mathematical calculations based upon his observations, they would show that the greatest velocity which he could ever induce in the target would be 1000 feet per second (the velocity of the bullets), and that to produce this velocity it would be necessary to fire an infinite number of bullets. His experiment demonstrates conclusively that as the velocity of the target approaches 1000 feet per second, his ability to further accelerate it approaches zero. Persons with lesser intelligence or insight than our observer might be convinced

that this figure of 1000 feet per second was an absolute and inescapable limit. The observer, however, as we said, has greater understanding. After he has accelerated his target to the 'limiting' velocity of 1000 feet per second (by firing an infinite number of bullets), he steps aboard a small space ship (with which he has thoughtfully provided himself), and takes off in the direction of the target. He accelerates his ship to a velocity of 1000 feet per second, with respect to his starting point, and now finds that he is back upon exactly the same energy level as his target. If there were no other bodies of matter in the universe, there would be no way in which he could determine that either he or the target were in motion, since there would be no relative motion between them, and no other reference points from which motion might be determined. In fact, he finds that the situation is exactly the same as it was before he fired the first shot, and he can now begin his shooting all over again. He does so and observes that his first bullet accelerates the target to a velocity of 500 feet per second with respect to his new reference point, and he notes that the 'infinite mass' of the target returns to its original 10 grams, as soon as he reaches the same energy level. He realizes then that the 'increasing mass' of the target is only the measure of the kinetic energy differential which exists between them. The mass approaches infinity only as the energy level approaches that of the accelerating force. (In this case

it is 1000 feet per second.) In the case of the quantity C, usually called the velocity of light, the differential is equal to 3×10^{10} centimeters per second, or if we convert this velocity to its equivalent energy we would have 9×10^{20} ergs per gram of mass.

CHAPTER THIRTEEN

RELATIVITY AND THE QUANTITY C

Earlier in this text reference was made to the theory of 'Special Relativity' advanced in 1905 by Dr. Albert Einstein. This is perhaps the most talked about and least understood cosmological theory which has ever been presented to the world.

The reason for most of the misunderstanding (which exists almost equally among scientists and laymen) is simply that the explanatory statement with which the theory was prefaced, has been ignored and omitted from almost every subsequent presentation of this work. Science has tended to take the concept which was called a theory of Special Relativity, and to attempt to forge from it a law of universal absolutes.

The result has been, as we mentioned earlier, the creation of the very thought blocks which Dr. Einstein had sought to prevent.

Let us consider for a moment, this forgotten preface. In it Einstein pointed out first, that all of the knowledge which we have or can obtain, concerning the universe

about us must come to us through our senses, since they are the only direct contact with reality which we have. "Therefore," he continued, "if we are to formulate mathematical rules or laws concerning that universe, we must begin with the postulate that what our senses tell us, is true." This means that if we observe, through a large telescope, the explosion of a nova in a remote galaxy, and at the same time observe the eruption of a volcano upon our own earth, we must, for the purpose of our mathematics, assume that these two events are simultaneous, because they are so observed.

This is a postulate which is difficult to accept, because the faculty which we call "reason" immediately interposes the objection that a separation in space involves an elapse of time between the event and our perception of it. However, Dr. Einstein pointed out that if we allow our reason to modify our observations before our mathematics are complete, we will be evolving a concept whose value is based entirely upon the validity of our reason rather than upon the accuracy of our observations. After our mathematics are complete, then we can allow reason to deal with the formula, but until the formula is complete, we must postulate that events which are observed simultaneously occur simultaneously insofar as that observer is concerned, and that therefore the simultaneity of events is a condition which depends entirely upon the position of the observer with respect to chose events.

Almost any student of physics today, be he a beginner or a graduate scientist will argue that no man can ever travel from the earth to the star Alpha Centauri in a period of less than four years, because the star is four light years distant, and because the 'laws of relativity' state that matter can never move with a velocity greater than that of light.

This is one of the prime fallacies which has been created by misinterpretation of the mathematics. The mathematics do not say that man cannot travel between the earth and Alpha Centauri in less than four years. They say only that no observer on earth can ever see him do it.

Let us see if we can create an example by which this statement may be more readily understood.

First we will assume that there is a plant in orbit about Alpha Centauri. (Because of Alpha's proximity to its Twin star 'Proxima Centauri,' the orbit would be a rather eccentric one, but perhaps it will do as a reference point.)

Next we will build a small space ship, in which we propose to pay a visit to this planet.

Since a small space ship is not a very comfortable place to spend long periods of time, the idea of being confined to the craft for the four years, which relativity seems to say is the shortest possible time, is a distasteful one, so we cast about for means to shorten the journey.

If we do our engineering according to the rules which are known as 'classical mechanics' or 'ordinary engineering practice', it will become apparent at once that we cannot use any source of energy which originates within the ship. These rules of mechanics tell us that, to accelerate a body of matter to a velocity of 3×10^{10} centimeters per second (the velocity of light) will require energy equal to 9×10^{20} ergs per gram of mass. Yet the rules of relativity ($E=MC^2$) tell us that 9×10^{20} ergs is the total energy contained in a gram of mass. This means that if we wish to accelerate the space ship to the velocity of light by energy created within the ship, we would have to convert all of the matter within the ship, including our own bodies to energy. We would then achieve the velocity of light, but we would arrive at our destination, not as matter but as electro-magnetic radiation.

Since we would much prefer to arrive as matter, we must seek an accelerating force which will act from some unlimited source of energy outside the ship.

It is at once apparent that a force field originating on earth would not be successful because the rate of propagation of a field is the same as that of light, and no field can accelerate us to a velocity greater than its own rate of propagation.

For the purpose of this example we will simply postulate that we have available, a supply of energy

from an outside source, which we can use in any desired quantity, and which can be used to create an instantaneous velocity so high that we will reach our destination, four light years distant, in a single hour.

We will take off from a launching pad which is situated near an observatory operated by a friend of ours, who is an astronomer, and who has a telescope of unlimited power, through which he will observe our progress. Since he can only observe us through the light which we emit during the trip, we must also cause the ship to emit a very large quantity of light.

At a prearranged instant we will takeoff and at once achieve a velocity that will take us to our destination in an hour. After fifteen minutes we will have covered one quarter of the distance, but the light which we emit at that point will require one year to return to earth, and will reach the eyes of the astronomer one year and fifteen minutes after takeoff.

He will note in his logbook that we required a year and fifteen minutes to reach the quarter point.

After we have traveled for thirty minutes we will have covered half the distance, but the light which we emit at that point will require two years to return to earth, and so will reach the astronomers eyes two years and thirty minutes after takeoff.

After an hour has passed we will have reached our destination, but the light emitted by the craft will not reach the astronomer until four years and one hour after our departure from earth.

All of the light which we emit at intermediate points will, of course, arrive at intermediate times so that the astronomer could observe our progress constantly from the instant of takeoff to the moment of our arrival upon the distant planet, four years and one hour later. According to the primary postulate of relativity that we must accept the evidence of our senses as being valid, the astronomer must maintain that from his reference point we did not quite achieve the velocity of light. The fact that we may have returned long before this, that we may be seated at his side, and may perhaps, be assisting him in his work, does not in any way affect the validity of his observations or the mathematics of relativity which he applies thereto. Let us remember, however, the statement that, "When our mathematics are complete, then we may allow reason to deal with that which we have created." If we do this, we will not fall into the common error of confusing relativity with a concept of absolute determinism.

CHAPTER FOURTEEN

NEW GALAXIES

At this point in our progress of understanding, we shall embark upon a most ambitious journey. We are going out into space. Into the remotest depths of inter galactic space, so that we may observe, at close range, the birth processes of a new star cluster or 'Galaxy.' We will take along our consciousness, our ability to observe, and our understanding. We must, of course, leave our bodies behind, since they would not fare well in space, and also because their mass would create a gravitational field which would tend to alter the natural conditions at our point of observation. We will seek a spot which is at least a few million light years distant from any other galaxy or accumulation of matter; for it is only within these remote areas that we may observe the birth process of a new galaxy.

In the first part of this book, we discussed the almost inconceivably large number of particles which are found in each cubic inch of our atmosphere at sea level. As we move outward from the earth's surface we find that the

number of particles diminishes rapidly, but still remains surprisingly large. When we have reached a height of one hundred miles we find that there are only about one millionth as many particles per cubic inch as we found at the surface, this is a density of matter so minute that we require very sensitive instruments, even to detect its existence. Yet, if we count the individual particles, we will find that there are still about 400 million, million particles in each cubic inch of space. At a few hundred miles elevation the density has diminished another million times, and we say that we have entered 'space', yet there are still many millions of particles per cubic inch.

We come to the startling realization that there simply is no such thing as 'empty space.' Astronomers have estimated that even in the remotest depths of intergalactic space, (which is our destination on this trip) there will still be found from twenty five to seventy five or more nuclear or atomic particles per cubic inch. Most of these particles are protons, or simple atoms which have attained escape velocity from the surfaces of some star, and which may have been wandering aimlessly about, perhaps for billions of years, coming into occasional collision with ocher particles, but usually with sufficient relative velocity so that mutual capture could not take place.

In the vicinity of existing galaxies, the gravitational fields created by the innumerable stars within those galaxies, tend to draw in the random particles, many of which

eventually fall into one or another of the stars, and thereby assist somewhat in replenishing the mass which each star is constantly converting into energy.

We must, therefore, seek a spot which is remote from any of the existing galaxies, and approximately equidistant from the nearer ones. Even in this remote area of space we will find countless numbers of particles of matter, anti units of charge; electrons, protons or simple atoms, which have achieved escape velocity from some star, or which have been formed in space by random approach and capture. In short, we have all of the building blocks of nature, present in an exceedingly tenuous and diffuse state.

Since each of the particles of matter has mass, each has a force of attraction existing between it and ever other particle of matter in the area.

If we accept the concept of the non linearity of natural law as previously outlined in this text, we find that each of these particles is also being repelled slightly by the surrounding galaxies or galactic clusters.

These forces are almost inconceivably small, yet the net result of their action is to create a tendency upon the part of each randomly moving particle to move ever closer to the center of the area of attraction, which is also approximately but not exactly the center or 'null balance' point of the repulsion of the surrounding galaxies.

We will assume that we have now reached the point from which we will observe the birth of our new galaxy.

This point is at the center of a sphere of space, perhaps thirty thousand light years in diameter, within which the final concentration of matter will take place.

We must be prepared to exercise a great deal of patience, because the forces involved, and the resulting accelerations are so minute that many millions of years will probably elapse before we can detect any significant increase in the number of particles per unit of volume. Nevertheless, all of the particles within several hundreds of thousands of light years are slowly but surely acquiring a velocity in our direction.

As the concentration of matter at the center of our system increases, the intensity of its field will also increase and will add, not only to the velocity, but also to the acceleration of the inward moving particles. We are observing the condensation of a tremendously large volume of exceedingly ratified gas into a relatively small volume.

Let us assume that one hundred million years have passed since we first occupied our point of observation at the center of the newly forming galaxy. All of the particles within some thousands of light years have now acquired a very respectable velocity in our direction, and the density of the gas surrounding us is increasing with comparative rapidity. We observe however, that the particles are not falling directly toward the central point of the condensation.

We can understand this if we realize that the center or null point of the force of repulsion is determined only by the distribution and the distance of the surrounding galaxies, while the center of the force of attraction is determined by the distribution of matter within the area of condensation. Since the center of 'push' is not at the same point as the center of 'pull', there is a tendency toward the creation of an angular velocity. That is: the particles, instead of falling directly toward the center, will tend to spiral inward. Eventually this rotational motion will become general throughout the mass.

The plane in which this spin begins is determined by the location of the existing galaxies and the relative density of particles in different parts of the condensing mass, but once begun, the motion tends constantly to increase as the condensation proceeds.

The particles which are upon either side of the central plane of spin tend to fall toward the plane as well as toward the center, while those particles which are nearly perpendicular to the center of the plane of spin rend to fall inward more rapidly because of their smaller rotational velocities.

Our gas cloud now begins to take on the shape of a disk with a somewhat oblate sphere at the center. The galaxy has begun to assume its final shape, though as yet, there are no stars within it nor does it emir any light. If we were to direct a large telescope on earth towards this gas cloud, we would not be able to see it at all. Since all of the light coming from the galaxies behind it is now being absorbed, we would see only that there was an unusually large dark area in space. We would probably refer to it as a 'dark nebula,' a tremendous body of gas, still somewhat rarefied according to our usual concept of gas; which emits no light, but which does absorb, and convert to lower frequencies, almost all of the light, and other forms of radiant energy which reach it from the countless radiating stars throughout the universe.

As the nebula continues to contract, areas of comparatively high density will develop in many parts of the mass. Each of these points will become a local center of gravity, and accelerated condensation will occur towards these points.

The gas cloud now becomes broken up into a multitude of individual spheres, each of which continues to condense upon its own center, just as a cloud condenses into myriads of tiny water droplets.

Let us now direct our attention to one of these 'droplets' which is eventually to become a star in our new galaxy. It is still several millions of miles in diameter, but shrinking rapidly.

As the gas cloud condenses, the energy which it contains, becomes concentrated. The particles which while they were drifting about in space, had almost infinitely long 'mean free paths', now come into more and more frequent and more and more violent collisions.

The temperature of the mass constantly rises. The kinetic energy which the particles have been building up during the millions of years while they were accelerating toward the common center, is now being converted into thermal energy. Eventually the mass begins to emit photons having frequencies in the visible portion of the spectrum.

We can now say that the star has been 'born', although it may still have more resemblance to a nebula, than to a star. A great deal more contraction will take place before the internal pressure of the gas begins to balance the gravitational force.

The star which we have chosen for observation is one of the millions which are forming within the central portion of the nebula. Since the nebula was created by the gradual inward movement of particles from an immense volume of space, it is apparent that it is within the spherical area at the center that the gas will first achieve a density sufficient for the process of condensation into separate stars to begin.

By this time the entire nebula has acquired a fairly uniform rotation about its center of mass. The individual stars, during their condensation, will of course retain this rotation but will also develop a rotational motion about their own center of gravity.

As the gas at the core of the new star becomes denser, the gravitational field becomes more and more

intense, and the surrounding matter falls, with ever increasing rapidity toward the center.

Most of the gas which, even during the dark nebula stage, occupied dozens of cubic light years, of space, now is compressed into a sphere only a few million miles in diameter.

Earlier in this text we observed that the temperature of a given gas will be inversely proportionate to the volume which that gas occupies, so long as the total thermal energy contained remains the same.

The gas which we are observing is now billions of times more densely packed than it was when the condensation began, and the temperature has risen from a fraction of a degree absolute, to several millions of degrees. This temperature continues to rise as the high kinetic energy which the incoming particles have acquired during their long fall, is converted into thermal energy as those particles impact the randomly moving particles at the surface of the star.

The condensation of the star, from the dark nebula to its present state of development has been comparatively rapid, only a few million years being required for the process. Most of the matter available to the star has now formed into a fairly compact spheroid, and comparatively little new matter is arriving at the surface.

As the mass continues to contract, the temperature within the body of the star continues to rise, but because of the tremendous amount of radiant energy which is

now escaping from the surface, its temperature will remain far below that of the interior.

The star is now a member of the class which Walter Baade, then a member of the Mount Wilson Observatory staff, named Population I, a blue white star with a surface temperature of the order of 30,000 degrees absolute, and an internal temperature of several millions of degrees. It is emitting light and heat energy at a rate much greater than can be replaced by the comparatively small amount of material which is still falling into it from the nebular cloud.

If the life process of the star ended here, its period of luminescence would be very short. Within a few thousands of years, the surface temperature would begin to fall below the point of incandescence and the star would appear as a dull red body. The continuing contraction of its mass might maintain the star in this condition for a few thousands of years more, but eventually the surface would become almost entirely dark, and a liquid or solid crust would probably begin to form.

We know, however, even from our relatively short history of astronomical observations, that the active period of a star is much greater than this. Let us, therefore, return to our nuclear scale of observation to determine the source from which the star receives its continuing supply of energy.

We must remember that much of the matter which forms our new star, consists of atoms which, eons ago,

escaped from the surface of some other star. Since the atom of normal hydrogen ($_1H^1$) is the lightest of the atom family, it will acquire, at a given energy level, a greater velocity than any other atom, and since velocity is the principal factor in the escape of atoms from the gravitational field of a star, we would assume that most of the particles to be found in open space would be hydrogen atoms.

The new, star, which is simply a condensation of these particles, would also be assumed to consist principally of hydrogen.

This fact, which we can predict from our simple study of the behavior of atomic particles, has been verified many times by spectrographic analysis of the newer stars in presently existing galaxies.

Let us examine the interior of the star, to see if we can discover the source of its great energy supply. (Since we left our bodies at home when we embarked upon this extra-galactic tour, we will not be unduly inconvenienced by the high temperatures and pressures which exist in the regions in which we must conduct our observations.)

As we approach the star, we first pass through a region which, in the case of our sun, we call the corona. It is the area about a star where the incoming particles first meet resistance in their long fall. The corona is a belt of exceedingly tenuous gas whose particles have random motions. This layer of gas is much like the upper

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layers of the earth's atmosphere except that its temperature is very much higher. We must remember that the tremendous gravitational field of the star is attracting particles from all parts of the space surrounding it, and that they acquire very high velocities. As they fall through the star's outer layer of gas, sooner or later, each falling particle comes into direct collision with a particle of the corona gas. The linear kinetic energy is converted to radiant energy of high intensity. We observe temperatures of one trillion degrees Fahrenheit and more. The gas is, however, so ratified that the total amount of heat created per unit volume of space is small compared to the much greater quantities of energy which are being radiated from lower levels.

After we have descended through the corona, we encounter another layer of gas, much denser than the gas of the corona. This layer we will call the photosphere, because it is within this layer that most of the visible light which the star radiates, is created.

Here the temperature, as measured by the activity of the particles, is much lower, only about 11,000 degrees F, yet the gas is so much denser that the energy contained per unit volume, is many times greater than that of the corona.

The photosphere is essentially the receiving and shipping department of the star, receiving great quantities of energy from deeper levels, and radiating that energy into space in a never ending stream.

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As we descend deeper into the body of the star, we find that the temperature and the pressure constantly increase. This means, of course, that as the gas becomes denser, the mean free path of the particles is becoming shorter, and their velocity is ever increasing. The frequency and violence with which the particles impact each other becomes almost impossible to describe or imagine.

As we approach the central core of the star, we find temperatures upward of twenty millions of degrees, and pressures in the billions of pounds per square inch.

Although the material is still technically a gas, because all of the particles have velocities greater than their escape velocity from each other, its density is now about ten times that of solid steel.

If we remember that in our atmosphere at 32°F and only 14.7 lbs. per square inch, the average particle has a velocity of 1760 feet per second, and undergoes five billion collisions per second, it may give us some faint comprehension of the number and violence of the collisions which take place between the particles deep within the body of a star.

We see that the shell of force which the planetary electrons create about the nucleus, is not sufficient to withstand impacts of this order, and the nucleus is soon stripped of its planetary electrons. When the bare nuclei impact other bare nuclei at this energy level we see that fusion of the two may, and frequently does take place.

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The fusion of two nuclei results in the formation of a single nucleus which has a mass slightly smaller than that of the two parts from which it was created. The mass which is lost, appears as a tremendous burst of radiant energy, most of which subsequently is converted to heat. We note that this fusion or joining together of nuclear particles may occur in a number of ways, but in every case where the resultant nucleus has a mass smaller than the mass of the atom of silver, large quantities of heat will be released as a result of the combination.

We also observe that when the mass of the resultant nucleus is greater than the mass of an atom of silver, a large quantity of energy is absorbed rather than radiated, but this event occurs so infrequently that only an insignificant amount of energy is thus subtracted from the total. It is this energy of fusion which constantly replaces that which is being radiated into space from the surface of the star.

The process of fusion also gradually builds up heavier elements from the hydrogen building blocks which were the principal material of the new star. Consequently we would assume that the life expectancy of a given star is determined largely by the amount of hydrogen which it has available for fusion.

If the principal subject of our study were astronomy rather than the larger field of cosmology, we might devote several chapters to the examination of the inherent stabilities and instabilities which affect the process of fusion

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within a star. If we had a few billion years to spare, we might watch the infant as it changed slowly from a medium sized blue white star, to a somewhat smaller and denser white, until the ever increasing instabilities of the nuclear reactions within it finally overcame the stabilizing factors, and the entire star suddenly erupted in the tremendous blast of inconceivable energy which we call a nova.

After a few months we would see all of the material which had not been blasted irretrievably into space, slowly settle back into a very small and exceedingly dense core which we would describe as a red dwarf.

Since we have already spent many millions of years in this observational expedition, perhaps it is time for us to consider returning to earth. After all, there are many interesting things going on there too!

Before we leave, however, there is one more pattern of development which we should observe because it is, to our own egos at least, the most important of all.

In the star which we have been observing, the condensation took place in a symmetrical manner, with the result that a single sphere was formed. If we had been able to observe all of the stellar condensations simultaneously, we would have observed that in approximately one our of four or five cases, the condensation did not proceed symmetrically. The reason for this is found in the position and size of neighboring condensations. As in the case of the galactic nebula, the stellar gas cloud also begins to rotate as it condenses, and again a plane of spin is

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created. The particles outside this plane of spin tend to fall toward the plane as well as toward the center. As the rate of spin increases, the gas at some distance from the center, approaches orbital velocity with respect to that center. In simpler words, the centrifugal force tends to balance the gravitational pull of the central mass, and secondary centers of condensation are formed which are in orbit about the principal mass. These secondary condensations are usually very' small in proportion to the main mass, just as the main mass is small in proportion to the galaxy.

(In extreme cases, the condensing cloud may divide into two or more roughly equal parts, each of which becomes a separate star, but which then arc in rotation about a common center of gravity.

It is in the smaller condensations however, that we are particularly interested at this point.)

These smaller bodies which, in the case of our solar system, we have named 'planets,' will always be found to contain a much larger proportion of the heavier atoms, than will be found in the body of the star.

The reasons for this fact become obvious from our previous examination of atomic behavior. In the first place, we have seen that the lighter atom has a higher velocity at a given temperature, and so will reach escape velocity from a given body at a lower temperature. The condensations which result in planetary bodies, being comparatively small, do not reach the very high

temperatures found in the stars, but they do reach temperatures sufficiently high to cause most of the lighter particles to reach escape velocity from the relatively small gravitational field.

Because the body is small, and the temperature low, such nuclear reactions as may occur under these circumstances do not furnish sufficient energy to replace that which is radiated, and the planet soon begins to cool.

A solid crust forms upon the surface, and the elements begin to combine in countless molecular patterns. When the surface has reached a sufficiently low temperature, the stage is set for the creation of the amino-acids which are generally conceded to be the starting point in the development of the organic forms to which we refer collectively as 'life'. The process is a delicate one, and only a small percentage of the planets may develop conditions suitable for this type of synthesis. It is also possible that the process may take place upon only a small percentage of those planets which do have suitable conditions. Yet, among the tens of billions of planets in a single galaxy, it is a virtual certainty, from a statistical standpoint, that synthesis will occur upon at least a few hundred, or perhaps a few thousand planets. (If we assume that the creation of life is directed by Divine Will, then the number might be much larger.) If we wished to follow the development of these first life forms through all of the stages of evolution required to produce a sentient being, we might have to

wait for a period of time as long as that required for the formation of the galaxy, but eventually such a genus would appear. A race of beings capable of originating complex thought patterns, followed by equally complex actions.

Sooner or later, such a race would tire of its confinement upon a single planet, and would seek means to broaden the scope of its investigations, and of its movements.

Having achieved space travel, the race would proceed to radiate in all directions from its point of origin, investigating many planets, and perhaps colonizing some of those which were suitable for life but upon which life had not yet developed.

We must recall at this point, that it is the central spheroid of the galaxy which is formed first. It is in the central portion, that planets would first reach conditions suitable for life, and it is upon these planets that life would first achieve a high degree of development. Intelligent life might therefore be said to radiate from the center of a galaxy outward toward the periphery. A process which might take place over a period of several millions of years after the first race had achieved space travel.

It is with this thought, and in a very humble frame of mind that we begin our return journey to our tiny planet earth; located almost on the extreme outer edge of our own galaxy.