The Mechanism of the Universe

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The human race, in its modern form, has been observing the universe from the surface of this planet for something like 50,000 years, perhaps as much as 100,000. But only within the last three or four thousand years has it had the capacity to analyze these observations and arrive at conclusions as to their significance. Yet on the basis of this extremely limited experience we somehow feel that we are competent to investigate events which, if they happened at all, happened ten or twenty billion years ago, and other events which, if they are ever going to happen, will not happen for an equally long time into the future.

This highly presumptuous undertaking, which goes by the name of cosmology, has thus far been left mainly in the hands of two special groups: the astronomers, who are the only ones that deal with objects and processes that persist over long enough periods of time to throw any light on the points at issue, and the theologians, who are the only ones that claim to have sources of information independent of experience. Since our discussion will be concerned with the scientific aspects of the subject, it will not be feasible to give any consideration to the religious contentions and to the non-scientific evidence that is offered in support of those contentions. It will be appropriate, however, to take a brief look at the information from which the astronomers are deriving their theories.

From the planets, particularly the one that we know best, the one on which we live, we obtain one very significant item of information. It is now clear that the earth is undergoing some changes of an irreversible nature—what we rather loosely call evolutionary processes. This point may not seem very significant, as it is now taken for granted. One should bear in mind, however, that it was not always taken for granted. On the contrary, during almost all of the history of the human race the belief was that both the earth and the heavens are fixed and unchanging. The definite evidence of the existence of irreversible processes on the earth is important because it is positive proof that the universe is not fixed and immutable; it is a universe of change.

Another result of the studies that have been made of our own planet is an indication of the time scale of events in the universe. By extrapolating the rates of some of the irreversible changes, such as radioactive disintegration, back to some assumed base condition, it has been found that there was a discontinuity of some kind about four or five billion years ago. This has been interpreted as representing the time of formation of the earth. Here, however, we encounter something that we need to watch out for, whenever we are attempting to assess the validity of scientific conclusions. If we examine the nature of the argument in this case, we find that the conclusions do not follow logically from the premises. Radioactivity is not a property of the earth as an aggregate; it is a property of the radioactive matter. If the calculated zero point indicates an age, it therefore indicates the age of the matter, not the age of the earth. This conclusion is not acceptable to present-day scientists, so they substitute one that is more to their liking. We should disregard it, and recognize that the observations actually tell us nothing beyond the fact that there was a discontinuity of some kind four or five billion years ago. For present purposes, that is sufficient, as it establishes the fact that we are dealing with objects and processes that persist through billions of years.

The definite knowledge that this is a universe of change becomes very important when we move from planets to stars, because there is little opportunity for direct observation of the changes that are taking place there. The time scale of astronomical events is so long that our observations give us little more than an instantaneous picture. But there are aspects of this picture that suggest change, and the knowledge that changes do take place justifies us in concluding, at least tentatively, that the indications of change are not misleading. However, our ideas as to the nature and directions of the changes have to be based mainly on assumption and inference. For example, stars come in a great variety of sizes and temperatures, but the great majority of them can be placed in a regular pattern known as the main sequence. In a universe of change there is good reason to believe that this is an evolutionary pattern of some kind, but unfortunately the pattern itself gives us no clue as to the direction of the evolution. It does not tell us which are the old stars and which the young. For an answer to this question we must examine some collateral data.

When we attempt to do so, however, we encounter one of the major problems of astronomy, and the astronomical view of cosmology. These collateral items to which we turn for a resolution of the question do not agree. In fact, as I will bring out later in the discussion, most of the purely astronomical evidence contradicts the prevailing astronomical opinion. What has happened here is that a very tentative conclusion as to the source of the energy of the stars that has been reached by the physicists has been accepted by the astronomers as incontestable, and has been allowed to override the astronomical evidence. The physicists have spoken; let no dog howl.

This is an example of another of the things we have to guard against when we undertake a critical examination of any field of knowledge: a tendency to magnify the observational information in transmission between the isolated compartments in which today's specialists work. The physicists know that their conclusions in this case are far from secure, and it is probable that those conclusions would be thrown overboard quickly if it developed that they were in conflict with any physical information, but by the time they have been passed on to the astronomers they have acquired the status of Holy Writ, and any doubt as to their validity is unthinkable.

A similar process of enhancement takes place whenever highly questionable assumptions are subjected to advanced mathematical treatment. By the time the original data have been put through a half dozen esoteric mathematical processes and an answer of some kind has been obtained, it is all too often forgotten that the whole construction rests on nothing but the thin air of an assumption. I am emphasizing these points because the biggest obstacle that stands in the way of arriving at an understanding of the remote regions and features of the universe is the existence of so many errors and misconceptions in what currently passes as knowledge. As one American humorist put it, some years ago, "It isn't what we don't know that hurts us; it is what we do know that ain't so."

In addition to the information that we get from the stars individually, the observations of stellar groups, clusters, as we call them, provide some further clues as to the nature of the evolutionary processes in which they are participating. Indeed, the clusters have been more informative on the subject of the direction of evolution of the stars than the stars themselves. Here again, however, it is by no means certain how the observational information should be interpreted, and consequently its significance has been open to serious question.

When we step up to the next larger aggregates of matter, the galaxies, we again find some similar patterns that shed some light on the cosmological question. This completes the astronomical contribution to the solution of the problem, aside from one new factor that has come to light very recently. But strangely enough, these astronomical observations, which constituted the entire basis for cosmological speculation until a few years ago, are now almost totally disregarded. Current cosmological theories make no attempt to connect the evolution of the contents of the universe—the galaxies, the clusters, the stars, the planets, the independent particles, and the non-material constituents—with the evolution of the universe as a whole.

The recent findings on which cosmological attention is now concentrated are those which show that the wavelengths of the radiation received from the distant galaxies are strongly shifted toward the red end of the spectrum. If these red-shifts are interpreted as Doppler shifts, the only adequate explanation that is currently available, the distant galaxies are receding from us at extremely high velocities which increase linearly with the distance. This indicates that the entire universe is undergoing a process of expansion. Obviously any cosmological theory must provide some kind of an explanation for the expansion, as it is clearly a significant feature of the cosmological pattern. As matters now stand, however, the cosmologists are concentrating their attention almost entirely on this one phenomenon, as if it were the whole problem. It would not be too far from the truth to say that the current theories of cosmology are nothing more than theories of the galactic recession.

If scientific questions were settled by majority vote, the winner in the cosmological race at the present time would be what is rather irreverently called the Big Bang theory. This theory accounts for the recession by extrapolating the observed rate of recession back to zero and assuming that at the time thus calculated, some ten or twenty billion years ago, all, or most, of the matter in the universe was contained in one dense mass, which, for some reason, exploded and ejected its contents at the high velocities that we now observe. The ultimate fate of the universe, on this basis, will be a situation in which all activity will cease because the constituents of the universe will be too widely dispersed to interact.

A variation of the Big Bang theory assumes that the forces of gravitation will ultimately overcome the outward motion, and will initiate a contraction that will terminate when the maximum density is again reached, whereupon a new Big Bang will occur. This oscillating theory visualizes a continual series of such cycles without a beginning or an end.

In the Steady State theory, the effect of the recession in moving the galaxies apart is offset by the continuous creation of new matter which forms new galaxies to fill in the vacant spaces resulting from the expansion, so that the universe, while always changing, always remains essentially the same.

All of these theories are subject to serious objections. The Big Bang is the least open to specific charges of error or inconsistency, but this is mainly because the theory consists almost entirely of untestable ad hoc assumptions. Of course, this is, in itself, a serious defect in the theory. The oscillating theory is subject to the same objections as the Big Bang theory, with the additional complication that it requires gravitation to be strong enough to eventually overcome the recession, whereas the indications are that the gravitational force is much too weak.

The strongest theoretical objection to the Steady State theory comes from those who are unwilling to sacrifice the conservation laws by admitting the continuous creation of matter that this theory requires. The history of the theory has been one of alternating rise and fall as additional evidence has accumulated. At the moment its fortunes are at a low ebb because of two recent developments of an adverse nature. The first of these comes from investigations of the relation of the number of astronomical radio sources to the distance. On the basis of these radio source counts it is now believed that the universe was more densely populated some billions of years ago than at present. This, if correct, would rule out the Steady State theory. Another item that is currently being given much weight is the discovery of an isotopic background radiation that is more or less consistent with the Big Bang and oscillating theories but is as yet unexplained by the Steady State theory.

Neither of these new findings is at all conclusive, so far as the validity of either theory is concerned. The radio source counts are open to serious question, particularly since no one knows with any degree of certainty just what kind of objects are being counted. Likewise, the possibility of an explanation of the background radiation that is consistent with the Steady State theory is by no means excluded. Nor is the explanation of the cosmic background radiation in terms of the Big Bang theory as good as is claimed; it is now conveniently forgotten that the temperature of the background originally predicted by the Big Bang cosmologists was significantly higher than the observed value. In any event, it should be recognized that disproof of one theory is not equivalent to proof of another. Even if the new observations are accepted at their face value, they contribute nothing toward establishing the validity of the central assertion of the Big Bang theory: the assertion that the recession of the galaxies is due to a primeval explosion.

This is the cosmological situation at the moment. For an overall appraisal of just how matters now stand I will quote two prominent scientists:

> This job—cosmology—starts with rigorous analysis and ends in flights of imagination. (Vannevar Bush)
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> All chains of reasoning in cosmology are elastic. Almost every observation interpreted to support one conclusion can, in the hands of a moderately adroit theoretician, be interpreted to support the opposite. (Irwin I. Shapiro)

I am going to present a look at this situation from a new direction. This new view will not utilize any of the information that the astronomers have gathered from their observations. Where I refer to this information at all, it will be only for purposes of comparison with the results that have been obtained theoretically. Nor will I make any use of the information that the ecclesiastics claim to have received through revelation of one kind or another. Instead, I will present a view that is derived entirely by deduction from basic physical premises. This view is now open to us because we have at our disposal a general physical theory—the theory of the universe of motion.

The most primitive condition in a universe of motion, the condition in which the universe is in existence, but nothing at all is happening, is one in which nothing exists but independent units of motion. Each such unit involves one unit of space in association with one unit of time, and the speed is therefore 1/1 or unity. This means that the physical datum, or reference level, on the natural basis, the basis to which the universe actually conforms, is not the mathematical zero, but unit speed.

Let us consider an object which has no capability of independent motion, and is not acted upon by any outside force. If this object occupies a spatial location, which we may call s, at some time t, then, since it cannot move, it must remain at the same location indefinitely. But in a universe of motion this object is not motionless with respect to the arbitrary stationary system of reference that we customarily utilize—it is motionless with respect to the natural system of reference. That natural system is moving outward at unit speed with respect to the stationary system, carrying all physical objects with it. Thus, the object in question does not remain at the point in a stationary reference system which we have called s. It moves outward from that location at unit speed, so that at time t + 1 it occupies spatial location s + 1.

Some may find this difficult to reconcile with their present beliefs. We are accustomed to viewing motion in the context of its relation to a stationary spatial frame of reference. If an object has no capability of independent motion, then it seems almost axiomatic to most that its speed is zero with respect to that stationary reference frame. But there is no good reason why the universe must necessarily conform to human ideas as to what is right and proper. The general physical theory that we have developed, a theory that describes how the universe actually behaves, not what any of us thinks is the way it ought to behave, tells us that, in addition to whatever other motions it may possess, every object in the universe is moving outward at unit speed away from all other objects, simply by reason of the motion of the natural reference system relative to the stationary system that we have arbitrarily selected as a frame of reference.

Here we have a very important conclusion that, as I have shown, is derived purely by deduction from the general properties of a universe of motion. It will not be possible to follow the lines or chains of deductions leading to other conclusions in this same detailed manner on this occasion. For present purposes I will merely indicate the points at which we will have to go back to the basic premises and follow a new chain of deductions, and I will specify the conclusions that are thus reached, to the extent that they are relevant to the subjects under discussion. The full details of the theoretical development are available in my publications and those of my associates.

One of these additional lines of deductions from the basic premises arrives at the conclusion that atoms of matter are combinations of rotational motions, and that the nature of these atomic rotations is such that they have a translational aspect. As an analogy, we may consider a ball rolling along the floor. This ball does not have an independent translational motion, as it would if it were flying through the air while rotating. It has no motion other than the rotation, but the effect of this rotation, under the particular circumstances, is to move the ball forward translationally. A further finding from the same chain of deductions is that the translational motion due to the atomic rotation necessarily opposes the outward progression of the natural reference system. Thus, in addition to the outward motion due to this progression, every atom or aggregate of matter is subject to an opposing inward motion. This inward motion is what we know as gravitation.

It has long been recognized that there are many physical phenomena that are not capable of satisfactory explanation on the basis of the only universal force (or motion, which is another way of looking at the same thing) that has heretofore been recognized; that is, gravitation. For example, Gold and Hoyle make this comment:

> Attempts to explain both the expansion of the universe and the condensation of galaxies must be very largely contradictory so long as gravitation is the only force field under consideration. For if the expansive kinetic energy of matter is adequate to give universal expansion against the gravitational field it is adequate to prevent local condensation under gravity and vice versa. That is why, essentially, the formation of galaxies is passed over with little comment in most systems of cosmology.

Karl K. Darrow made the same point in connection with the question of inter-atomic equilibrium in the solid state, emphasizing that one force alone, whatever it may be, is not sufficient. There must also be what he called an “antagonist”. Darrow went on to say, “This essential and powerful force has no name of its own. This is because it is usually described in words not conveying directly the notion of force.” The globular star clusters provide still another example of the same kind. Like the formation of galaxies, this situation is “passed over with little comment” by the astronomers, but E. Finlay-Freundlich discussed it at length in a publication of the Royal Astronomical Society some years ago. He noted that gravitation is the only force available to the theorist, and on this basis, he says, “the main problem presented by the globular clusters is their very existence as finite systems.”

Identification of the “antagonist” to gravitation, the outward progression of the natural reference system, not only resolves these specific problems, but also throws new light on many other physical situations. An important point in this connection is that the net resultant of the two opposing motions varies with the distance. The inward motion due to the atomic rotation originates at the specific locations occupied by material aggregates, and it therefore decreases with distance in accordance with the inverse square law. The outward progression of the reference system is effective everywhere. It follows that at the shorter distances the gravitational motion is the greater, and all objects continually move toward each other, unless they are subjected to external forces. As the distance increases, the gravitational motion decreases, and at some point reaches equality with the outward motion of the reference system. Beyond this point the net motion is outward, increasing toward the speed of light as the gravitational effect is continually attenuated.

Here, in these immediate consequences of the concept of a universe of motion, we have an explanation of the recession of the galaxies that comes directly out of basic theory, and requires no ad hoc assumptions. But it should now be evident why I raised the question with respect to the current belief that the answer to the galactic recession is the answer to the whole cosmological problem. The explanation of the recession at which we have arrived does not solve the problem; it merely rules out the ad hoc assumptions that have been made, and thereby deepens the mystery. The ultimate fate of the receding galaxies is still a wide open question, and the origin of the galaxies is more of a problem than before. Continuous creation is inconsistent with the basic elements of the new theory, and the Big Bang concept is eliminated from consideration, as the recession has been identified as due to a different cause. But the galaxies that formerly occupied the regions just beyond the gravitational limits have moved away, and yet there is no additional vacant space. Where did the present occupants of these regions come from?

We can approach this question most conveniently in a sort of roundabout way. Another line of deductions from the basic postulates, an extension of the deductive chain from which we arrived at the nature of the atomic structure, discloses that this this atom is subject to an age limit. When an atom of matter arrives at the limiting age its rotational motion reverts to the translational status; that is, the atomic mass is converted to energy. A further line of deductions leads to the conclusion that most of the oldest matter accumulates in the interiors of the largest galaxies. The attainment of the age limit on a massive scale in one of these giant galaxies results in a tremendous explosion, which accelerates portions of the remaining mass of the galaxy to a speed in excess of the speed of light. The question then becomes, What happens to this fast-moving matter?

For an answer to this question we need to return to the fact previously deduced that space and time are the two reciprocal aspects of motion, and nothing else. This means that the reciprocal relation is a general relation that is effective throughout the universe. An immediate consequence is that for every physical entity or phenomenon there necessarily exists another entity or phenomenon that is similar in all respects except that space and time are interchanged. The inversion may be only partial, applying to only one of the motions involved—the translational motion, for example—or it may apply to all of these motions. All of the familiar entities of our material universe are therefore duplicated in the inverse manner, which leads to the conclusion that what we have been regarding as the physical universe is actually only one half of the physical universe as a whole. There also exists an exact duplicate, differing only in that wherever space is involved in any of the phenomena of our material sector, the inverse, or cosmic sector, as we will call it, substitutes time. Where we have time, it has space.

The next question that naturally arises is, Where is this cosmic sector of the universe? Here we need to look at the speed magnitudes. As already brought out, the natural reference system is moving at unit speed, which we can easily identify as the speed of light. In our material sector the prevailing speeds are less than unity, and the result is motion in space. In the cosmic sector, where space and time are interchanged, the speed is greater than unity, and the result is motion in time: a change of location in three-dimensional time that is analogous to the changes of location in three-dimensional space that result from motion at speeds less than unity. Thus each of the structures of the cosmic sector—the cosmic stars, cosmic galaxies, etc.—is separated from us by a certain amount of time, just as there are spatial separations between our location and the various structures of the material sector.

We receive the same kinds of information from the cosmic sector that reach us from the distant regions of the material sector: (l) radiation, and (2) individual particles of matter. But gravitation in the material sector is a motion in space, and it produces aggregates in which the constituent atoms are contiguous in space but widely dispersed in time. The radiation received from such an aggregate is therefore highly concentrated in space, and since we are approximately at rest in space relative to the emitting aggregate, we can recognize the radiation as coming from a discrete object. However, gravitation in the cosmic sector is a motion in time, and it produces aggregates in which the constituent atoms are contiguous in time but widely dispersed in space. The radiation from these aggregates reaches us from the widely dispersed spatial locations, and instead of being concentrated in the manner-of radiation from a material star or galaxy, it is spatially isotropic. This is the background radiation that has been interpreted as evidence in favor of the Big Bang theory. We likewise encounter cosmic stars and galaxies from time to time, but because of the way in which their constituents are dispersed in space we encounter them as occasional single cosmic atoms rather than as aggregates.

At this point I must report, rather regretfully, that the Reciprocal System of theory is a great disappointment to the devotees of science fiction. Many of them are full of anticipation when they first hear that the theory involves motion in time, but their hopes are dashed when they find that time travel in a universe of motion is subject to exactly the same kind of limitations as space travel. If we have sufficient time at our disposal, we can always return to a specific location in space by means of space travel, but we cannot return to the same place at the same time: we can only get there at some later time. Similarly, by means of travel in time, it would be possible, in principle, to return to any time location, but we cannot return to the same time at the same place, we can only reach that time location at a distant place.

We likewise have to say no to anti-gravity devices. Superman will have to stay in the comic sections. Gravitation is a motion, and the only anti-gravity device is an opposing motion. Now I will have to deepen the gloom by consigning the anti-matter energy generators to the same discard pile. There are aggregates of anti-matter (or cosmic matter, as we prefer to call it) to be sure. There are anti-matter stars, clusters and galaxies. But these are aggregates in time, not in space, and we meet them only one atom at a time.

To make matters worse, we will also have to discard what we may call the sanctified science fiction, the many products of the imagination ranging from the fanciful to the fantastic that have been injected into conventional physical and astronomical theory by investigators and theorists who have been frustrated in their attempts to solve their problems in an orderly scientific manner. Such ad hoc concepts as black holes, quarks, the Big Bang, curved space, etc., are no more scientific than anti-gravity devices. They have no place in the new system. In fact, this system outlaws ad hoc assumptions altogether.

Returning to cosmology, we now have the answer to the question as to the fate of the galactic fragments thrown off at speeds greater than the speed of light by the explosion of the galaxy. These fragments are observable for a time until the effect of gravitation is overcome, after which they enter the cosmic sector, the region of speeds above unity, and the matter of which they are composed then becomes available for the building of cosmic galaxies. These galaxies recede from each other, they and their constituents age, just as the material galaxies and their constituents do, and eventually the oldest cosmic galaxies explode and eject fragments at speeds less than unity. The fragments enter the material sector and become available as the raw material from which new galaxies are formed.

This, then, is the answer for which cosmology has been looking. As the proponents of the Steady State theory have contended, the universe had no beginning, and it will have no end. It has always existed in essentially the same form, and it has essentially the same appearance from any point in space or any point in time. But there is no continuous creation, nor do the galaxies simply disappear over the "time horizon," as in the Steady State theory. In a universe of motion the large-scale action of that universe is a cyclic process. Each half of the universe goes through an evolutionary sequence that begins with the entrance of matter from the inverse sector, transforms this matter into compatible structures, gathers it into aggregates, separates the aggregates, and finally subjects them to phenomena that result in the ejection of matter back into the inverse sector. A similar process in that sector completes the cycle.

For the benefit of those who may be reluctant to accept the idea of a universe without beginning or end because of a conflict with the religious idea of an act of creation, I will say that our findings do not affect the creation issue one way or the other. If the universe of motion came into being through an act of creation, then space and time were the entities that were created. There could be nothing before time existed, and if it came into existence as a result of an act of creation, the universe that was created could just as well be cyclic as open-ended.

Having established the general nature of the cosmic cycle, let us now take a closer look at its principal features. One of the advantages of a general physical theory is that the deductions we make from it do not have to be confined to generalities. We can go into as much detail as we wish, or, in this case, as much as we have room for. The matter ejected from the cosmic sector arrives in the material sector in the form of atoms of the cosmic elements, together with sub-atomic particles. The current belief is that these incoming particles, the cosmic rays as they are called, are atoms of the material elements, but the available means of identifying the original cosmic rays are not capable of distinguishing between the cosmic and material atoms. Furthermore, the subsequent behavior of these particles shows that they are not ordinary material elements. If they were, they would maintain their identities at least until they made some violent contact with other matter. But this is not what happens. If these atoms do not make contact quickly, they disintegrate spontaneously.

This is not the place to give a detailed account of the complex process by which the cosmic elements are transformed into structures that are compatible with the material environment. I will merely say that the end product is hydrogen, and this new hydrogen is the raw material from which the new structures of the material sector are built.

It is recognized by the astronomers that any evolutionary theory of the universe must regard the aggregates of matter such as stars and galaxies as having been formed by condensation from dispersed matter. But just how this can take place is a difficult question that, as Gold and Hoyle pointed out in the statement that I quoted earlier, they prefer to avoid. But the continual arrival of new supplies of hydrogen derived by modification of the cosmic matter received from the cosmic sector provides the answer to this problem.

Let us consider a spherical volume of space containing a uniform distribution of hydrogen atoms and sub-atomic particles. These particles, small as they are, are subject to the same two basic forces, or motions, that account for the translational behavior of the galaxies. The outward progression of the reference system carries each particle away from all others, while at the same time the gravitational motion carries all of them inward toward each other. The outermost particles of this spherical volume of matter are subject to the gravitational effect of the entire mass, as well as the interactions with their immediate neighbors, but in relatively small volumes the progression still predominates, and the aggregate tends to expand. As larger and larger volumes are taken into consideration, however, the mass, and consequently the total inward force, increases as the third power of the radius, whereas the effect of distance is a second power function. At some very large volume, therefore, the total gravitational motion of the outer particles exceeds the progression, and the entire aggregate of diffuse matter arrives at an equilibrium between the inward and outward motions.

Such an aggregate still has no unbalanced force that would cause it to contract, but the continual introduction of additional matter from the cosmic sector changes the situation, inasmuch as it strengthens the gravitational forces and moves the equilibrium inward. As this contraction of the volume occupied by the aggregate continues, and the density of the enclosed matter increases, local aggregates begin to build up within the occupied volume, and the ultimate result is a globular cluster, in which a million or more stars form a spherical aggregate.

The globular clusters have been an astronomical puzzle of long standing, as it is quite evident that they are stable and long-lived structures, but no adequate explanation has been available as to why the gravitational forces that hold such a cluster together do not cause its constituent stars to coalesce into one single mass. The progression of the natural reference system supplies the answer to this problem. The globular cluster is still subject to the same considerations as the spherical aggregate of diffuse matter from which it was formed. Like the interior particles of the diffuse aggregate, each of the stars in the interior of the cluster has a net outward motion. But the outer stars have net inward motions, and an equilibrium is established between these inward and outward motions.

The region under the gravitational control of a star within the cluster meets the region under the control of its neighbor at a point where the gravitational force of each star is near the minimum. Each star is therefore outside the gravitational limit of its neighbor, and because its net balance of motions is outward, it can never get inside this limit. The diffuse aggregate from which the globular cluster was formed contacts its neighbor at a point of maximum gravitational force, and the gravitational limits of neighboring aggregates therefore overlap. The increase of mass due to the incoming cosmic matter extends the limits still farther, and by the time the globular cluster stage is reached, each cluster is well within the gravitational limits of one or more of its neighbors. The clusters therefore move toward each other, and eventually some of them make contact.

The prevailing opinion is that because of the immense distances between the stars, the stellar aggregates participating in such an encounter would pass through each other with no significant interaction. Our findings indicate that this view is incorrect. Inasmuch as the stars of the cluster occupy equilibrium positions, the aggregate has the general characteristics of a liquid, and the actual result of contact is an amalgamation of the clusters. The resulting combination, with a population of two or three million stars, is classified as a dwarf galaxy. Its larger mass, as compared to that of the original cluster, greatly increases its gravitational force and improves its ability to capture additional clusters. If it keeps out of the clutches of still larger galaxies, the small galaxy ultimately becomes a large galaxy.

This picture of the situation is in direct conflict with much of current astronomical thought. Although no consensus has been reached on the issue as to how, and under what circumstances, condensation from the original diffuse matter occurred, conventional theory regards the galaxies, rather than the globular clusters, as the original products of the condensation process, and views the globular clusters as very old features of the galaxies. According to our findings by deduction from fundamental physical theory, the stars of the globular clusters, instead of being the oldest of those that are optically visible to us, as conventional theory asserts, are the youngest of the observable stars. In view of this direct conflict, it would be of interest to review the available evidence to see just how well each of these conflicting theories agrees with the information from observation. Unfortunately, the remaining space will not permit a detailed review of this kind, but I can say that I made a critical comparison of the two conflicting explanations of the status of the globular clusters a few years ago, in which I examined the assertions of each theory with respect to fifteen sets of facts which can be considered to represent practically all that is now known about the clusters.

In this investigation I found that conventional theory furnishes fully acceptable explanations for three of these fifteen items, partially satisfactory explanations for three more, unsatisfactory explanations for three items, no explanation at all for four items, and is definitely in conflict with the facts in two cases. The deductions from the postulates of the Reciprocal System, on the other hand, furnish full and detailed explanations for every one of these fifteen items. While, as I said, space does not permit a full discussion of these results, I am rather reluctant to make statements such as the foregoing without at least some substantiation, and I will therefore comment briefly on two of the items, to give an idea of the basis for my conclusions.

First, let us consider the motions of the clusters. In the words of Struve, they move "much as freely falling bodies attracted by the galactic center." Our theory says that this is exactly what they are and how they should move. Conventional theory is able to explain such motions only on the basis of some highly implausible assumptions.

As an illustration of another type of pertinent information, observations of the star clusters within the galactic disc show that these groups are not stable, and are disintegrating at a relatively rapid rate. The large number of such clusters now in existence in spite of the short indicated life means that some process of replenishment must be operative. Our theoretical development tells us that the supply is replenished by globular clusters which fall into the galaxy and break up. The astronomers have no explanation at all. Bok, for example, says "we do not pretend to know from where the galactic clusters come." He admits that it would be "tempting" to regard the globular clusters as the source of the replacements, but this would challenge the physicists' conclusions as to the source of the stellar energy and, of course, that is unthinkable.

There is no limitation on the process of capture from the environment which continually increases the size of a galaxy. So far as the capture process itself is concerned, the growth could continue indefinitely. However, the existence of an age limit also limits the galactic size. When this limit is reached the material phase of the great cycle of the universe of motion terminates.