PHYSICS.—*Cosmological theories—ancient and modern.*[1]

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In the month of December 1955 radio astronomers of the Naval Research Laboratory had their high-resolution radio telescope focused on Cygnus A. They were constructing a power spectrum across the region of the hydrogen spectrum line at 21 cm wavelength. They were looking for a dip or absorption line in the spectrum, which would occur if the energy received were passing through or were eclipsed from a hydrogen cloud. Furthermore, they were looking specifically for such an absorption line at a wavelength longer than 21 cm, which would occur if the hydrogen cloud were associated with Cygnus A source and therefore moving as Cygnus A is believed to move relative to the earth. On December 27 they found exactly what they were looking for. And when, by careful measurement and calculation, they derived the apparent velocity of recession from the earth, they found it to be 16,700 km per second. This agrees with a similar conclusion based on optical red-shift data to within less than 1 percent.

Let us look for a moment at what is back of this remarkable observation. It can hardly be called a new scientific discovery, since it was so confidently expected on the basis of all our other knowledge concerning our universe. Nor can those who conducted the experiment be said to be superior to other radio astronomers because they made the observation, since the experiment was made possible by the fine precision instruments made available to them. What were these instruments, and how did they come into being?

The instruments consisted primarily of a large, precision-built radio antenna, an accurately controlled servo-driven antenna mount, a high-gain, highly stable, selective, tunable, radio-frequency receiver, and a precision frequency control. These are all products of a relatively new field of endeavor, radio research and engineering. A considerable portion was built after the war, based in part on the results of wartime research. As a radio astronomy facility it has been in existence less than 10 years.

May we now turn to the much larger subject, our other knowledge concerning our universe which prompted the radio astronomers to look in the direction of Cygnus A, for the hydrogen radio frequency absorption line, at an augmented wavelength? The hydrogen absorption line at radio frequency was first observed in 1954 by radio astronomers of the Naval Research Laboratory using the apparatus just mentioned. Its existence was expected because the hydrogen radio-frequency emission line had been observed, first at Harvard University in March 1951, and subsequently in Holland and Australia.

Now we ask the question: What led to the hydrogen emission line observation at Harvard in 1951? The answer is simple. The radio astronomers there were looking specifically for that signal. They were looking for it because they had the precision radio astronomy instrumentation capable of detecting it if it were there, and the Dutch astronomer H. C. van de Hulst had predicted seven years earlier, in 1944, that such line should exist. In fact, van de Hulst was at Harvard at the time the observation was made, and I should not be surprised if he actually stimulated the Harvard astronomers to conduct the experiment, if, indeed, he did not himself participate in it.

But now we face another question: What led van de Hulst to make such a prediction? A commonly accepted model of the hydrogen atom is a proton nucleus about which orbits one electron. Both proton and electron spin on their own axes. The two spin axes of any one hydrogen atom at any particular time may be either parallel or antiparallel, i.e., while the proton spins in one direction of rotation, the electron may spin either in the same or in the opposite direction of rotation. Since both proton and electron are charged particles, their spin axes are also their magnetic axes. When their magnetic axes are

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parallel they repell each other and the electron orbit is slightly enlarged, resulting in a slightly increased potential energy state. When their magnetic axes are antiparallel, they attract each other, resulting in a slightly decreased potential energy state. The energy difference between these two states, when the electron is in the base orbit, was calculated by van de Hulst and divided by Planck's constant to yield the frequency value 1,420,405,000 cycles per second, or approximately 21 cm wavelength. To radiate energy at this wavelength, the hydrogen atoms must receive energy from some external source, in sufficiently large units to raise the atomic potential energy from the lower to the higher of these two levels, or, in terms of our model, to reverse the direction of the spin axis of the electron relative to the proton. Then, since this is not a stable state of affairs for the atom, the spin axis will flip back to its normal state, and in the process, radiate one quantum of energy at a wavelength of 21 cm. Van de Hulst then called attention to the possibility of this mechanism.

To trace to their origins the concepts on which van de Hulst made his suggestion would be far too involved for present treatment. It would lead us back through atomic theory, electricity and magnetism, optics, classical and statistical mechanics, mathematics of almost every branch, and a large array of scientific instruments. We shall simply leave it at that.

Thus far we have dealt only with one of the three questions we raised: Why were the radio astronomers last December looking for a hydrogen absorption line in the region of 21 cm wavelength? Let us now turn to a second one of the three questions: Why were they looking for an elongated wavelength?

The answer again is simple. The visible light we receive from distant galaxies is similarly elongated in wavelength. Let us explore the basis of this simple but somewhat categorical answer. We just considered a hydrogen atom to be a proton nucleus with an electron circling around it in one of several possible orbits. The atoms of all the other elements are likewise considered as consisting of nuclei in which protons predominate, and about which a number of electrons circle in a number of possible orbits. And as in the hydrogen atom, so in all atoms, energy may be absorbed in moving one or more electrons from their normal orbits to orbits of higher potential energy, whereupon the normal state will restore itself with the release of the absorbed energy in the form of electromagnetic radiation, at a frequency which is directly proportional to the energy difference between the two levels involved. The atoms of each element have a pattern of electron orbits which differs from the corresponding patterns of all other elements. When an element is excited so as to produce these energy transfers, the pattern of frequencies radiated is a "fingerprint" of that element. The pattern of frequencies is obtained by passing light from the excited element through a spectrometer, which separates the incident light into its frequency components and indicates the intensity of each frequency present. When light from distant nebulae is caught in an astronomical telescope and focused on a spectrometer, the spectra or "fingerprints" of known elements are found, but the wavelengths of all the spectrum lines from most of the nebulae are elongated. The light, in other words, is shifted toward the red end of the spectrum. Scientists have taxed their imaginations to explain this red-shift, and the only suggestion that satisfies is that it is produced by the Doppler effect of relative motion. In other words, the galaxies are moving away from us.

Now we could probe much more deeply into the origins of all the concepts touched upon but lightly here, of how J. J. Thomson discovered the electron, of how Ernest Rutherford discovered the hydrogen nucleus and postulated the basic structure of our present atomic model, of how R. A. Millikan measured the charge of the electron, of how Max Planck developed the quantum theory and arrived at the constant of proportionality between energy and frequency, of how Nils Bohr applied this theory to Rutherford's atomic model to give us our present atomic theory, of how the spectrometer works and what led to its invention, and of all the science and engineering that is associated with the invention and operation of astronomical telescopes, and of photosensitive

emulsions, and the optics and chemistry and mechanics of their use in both telescope and spectrometer. Many books have been written on these subjects, and to most of us they have become such an "old story" that we tend to take them for granted and forget the extent of our indebtedness to a long succession of technological developments in instrumentation for scientific observation which provided the means for all the scientific discoveries mentioned here, and from which we have inherited a galaxy of precision instruments that would completely mystify the ancients. But in these instruments, their skillful use, and the careful and clever interpretation of the data they provide, lies the answer to the question: "Why were the radio astronomers looking for an elongation of the hydrogen line wavelength that is normally 21 cm?"

We come now to the third question: Why were they using Cygnus A as a source for making this measurement? The answer to this leads into cosmological theory, the foundation for which has been partly developed in answering the other two questions. Cygnus A was unknown to astronomy until discovered by radio in 1948. It was then thought to be a part of our own galaxy, although the possibility of its being extra galactic was pointed out. When the 200-inch optical telescope was turned in its direction to investigate, Cygnus A was found to be two galaxies in collision, with the red-shift in its spectrum indicating a distance of tens of millions of light years. Needless to say, this discovery created considerable excitement in astronomy, particularly in the field of radio astronomy, and it became a matter of great interest to determine whether a frequency shift in the radio frequency hydrogen line might be found to correspond to the optical red-shift.

We have shown how distant galaxies appear to be flying away from us as sparks from the blacksmith's anvil. We have stated that more remote ones appear to be receding faster, but we have said nothing about why we think the greater apparent velocities are associated with greater distances. How do we measure these distances anyway? Let us start with the shorter distances, say a few tens or hundreds of light years. First, we must have a reference distance, or "measuring stick." This is the diameter of the earth's orbit about the sun. By recording the difference in position of a nearby star relatve to the remote stellar background between two measurements made six months and some 186 million miles apart, the distance to that star can be calculated. This method of measurement gives good results out to about 100 light years, less accurate but usable results to several hundred light years, and can reach about 5,000 stars. For greater distances a particular type of star called a Cepheid variable is used. A Cepheid variable is a star that pulsates in brightness with a period of from a few hours to many days. The absolute brightness of such a star has been found to be directly proportional to its period of pulsation. The constant of proportionality was determined by observing the periods and apparent brightnesses of Cepheid variables in our vicinity, where distances could be determined by triangulation and by star motions. Actually there are two types of Cepheid variables, blue giants and red giants. For a given period of pulsation, the red giants are about 1½ magnitudes brighter than the blue giants. This "double standard" was not fully appreciated and accepted until only two or three years ago. It was the discovery that the Cepheid variables near us, used for calibration, were all blue, while the remote ones used for distance measurement were red giants, making the measuring stick in use more than twice as long as it was thought to be, that doubled all remote astronomical distance and time estimates only just recently. Gamow gives the factor as 2.8.

Cepheid variables are available for determining astronomical distances as far as they may be resolved as individual stars and their variations measured with telescope and photomultiplier. With the 200-inch telescope, this is about 20-million light years. Now we have one measuring technique that takes us out to 100 light years, and another that takes us out to 20-million light years. Yet another is needed for the many galaxies visible to the telescope but beyond the range at which individual stars may be resolved.

We have in fact two such measuring techniques. The first is apparent brightness.

Nearly all galaxies seem to have the same absolute total brightness within a factor of approximately two from the mean value. By assuming mean absolute brightness and measuring apparent brightness, distance may be calculated hopefully within a factor of two. The other technique uses the spectrum red-shift. Since those galaxies whose distances may be measured by Cepheid variables which they contain show a red-shift proportional to their distance from us, it is not unreasonable to assume that this law of red-shift holds for greater distances, at least within certain limits. Red-shifts have been measured out to a shift of a little over 20 percent, corresponding to a recession velocity of 38,000 miles a second, and a distance of about a billion light years if the law holds that far. For greater distances, apparent brightness remains the only clue to distance. On that basis the present maximum reach of the 200-inch telescope is approximately 2 billion light years. It must be remembered, however, that at that distance we see galaxies as they appeared 2 billion years ago—time enough for significant changes to occur in their brightness. Also, if the law of red-shift holds at that distance, indicated recession velocities would be on the order of one half the velocity of light, and relativistic effects may be present. No one has yet been sufficiently daring to suggest what influence these effects might have on apparent brightness, if, indeed the elementary spectra or "fingerprints" of the atoms themselves may not be altered.

All this while we have been explaining why radio astronomers made a certain observation last December. In so doing, we have reviewed enough elementary astronomical observations to discuss modern theories pertaining to the nature and origin of the universe. We start with the assumption that the laws of nature are uniform and consistent throughout all space and all time. If remote bodies are receding from us they must at some time in the past have been much closer to us and closer together. In fact, if their relative velocities are proportional to their relative distances, extrapolation backward in time should yield a definite time in the past when all the matter of the universe was tightly packed in one place, from which it is exploding like one great super atomic bomb. This extrapolation places the time of explosion about 4 to 5 billion years ago. This view is held by a number of scientists, one of whom, George Gamow, has given us a fairly detailed account of how it might have happened. We will not attempt to probe into the scientific bases of this account, as Gamow and others have done, but rather attempt to describe a probable sequence of events.

In the original tightly compressed state, which is the earliest state science can know anything about, the temperature would be too high for matter to exist at all, and all the sum total of the matter and energy of the universe would be in the form of radiant energy. Thus the earliest phenomenon that can be postulated with any scientific foundation is a blinding flash of light intense beyond the capabilities of human imagination to conceive. On expanding from its point of origin, it would cool, at first with extreme rapidity. Five minutes after the first generation of this energy, the temperature would have cooled down to a billion degrees. At this temperature, protons, neutrons, and electrons could exist, but not atoms. In the succeeding 25 minutes all the chemical elements would be formed, for at the end of the first half hour the temperature would have dropped too low for nuclear reactions to take place. Calculations of the relative abundance of the elements that would result from such a process agrees remarkably well with what is found to exist today. Also, the state of decay of radioactive elements indicates that they were originally formed about 5 billion years ago.

Today the mass density of matter in the universe far exceeds the mass density of radiation. If, as has been postulated, the universe started out as all radiation, there must have been a time when the total mass density was equally divided between radiation and matter. On this subject let me quote from Gamow. "Computing the mass densities of radiation and of matter at various epochs, we can find the date of the great event when matter took over from radiation, i.e., surpassed it in mass density. The date was about the year 250,000,000 A.B. (After the Beginning). The temperature of space

was then about 170 degrees absolute, and the density both of radiation and of matter was comparable with the present density of interstellar gas. The Universe, in short, was dark and cool." This statement appeared in the March 1954 *Scientific American.*

The gradual transition from radiation to matter has been likened to slow precipitation of a solid from solution. As matter gained the ascendency over radiation, it began to react to the forces of turbulence and gravitational attraction, and formed into great clouds of gas. In time these clouds contracted by gravitational attraction to form the beginnings of galaxies. But turbulence, consisting of eddies within eddies ad infinitum, produced many secondary and tertiary centers of contraction, so that the clouds of gas "coagulated" into small "lumps," which in turn fell into larger ones, until whole hierarchies of suns and planets and satellites were formed. The pressures created by gravitational attraction produced local heating, the larger accumulations becoming quite hot. The maximum temperature thus produced in any star depends on the mass of the star. To reach surface incandescence requires a mass about 2,000 times that of the earth. Some galaxies are imbedded in gas and still growing. They are blue in color and spiral in form. Others have used up all their gas, and are cooling off. They are red in color and globular in form.

We have given in brief outline one of the two principal modern theories of cosmology. It is based on observed physical phenomena and analogous mathematical models. Whether the present hyperbolic expansion was matched by a corresponding hyperbolic contraction before the point of maximum concentration, or whether the primeval flash of light was an original creation must forever remain beyond the reach of science to decide. The fact remains that this theory provides a satisfactory scientific explanation for an amazingly wide variety of observed phenomena. Furthermore, it yields a value for the age of the universe which is remarkably consistent with no less than 12 other and mutually independent indications of that age. Space does not permit exploration of all these other methods, for we have other theories to consider.

One of these other theories is also a modern one, having originated only a few years ago, before discovery of the two populations of Cepheid variables. Two objections were raised to the "explosive" theory. One was the discrepancy in the age of the universe dictated by the theory as it then appeared. The other was that it tended to support the Biblical account of creation, a situation some found to be unpalatable. So in 1948, Bondi and Gold, as well as Hoyle, advanced a "steady-state" theory, in which matter is created continuously, one proton at a time, throughout the universe, to replenish the fleeing supply. A mathematical model has been constructed on this concept and made to fit present observations. It must be recognized, however, that the steady state theory is pure conjecture and has not a single experiment or physical observation to support it that does not also support the explosion theory. Furthermore, instead of disagreeing by a factor of 2 or 3 with other methods in indicating the age of the universe, it makes the universe eternal. Since its introduction, however, the correction to the astronomical measuring rod has brought the explosive theory of Eddington, Lemaître, Gamow, and von Weizsacker into complete harmony with other methods of age determination. That leaves only one argument for the continuous theory over the explosive theory: namely, it appears to contradict the Biblical statement of creation. Even in this matter however, it does not fully escape criticism. If matter has to be created out of nothing ultimately, is it any greater miracle to create one neutron at a time, than to do it all at once? Certainly there is difference in degree, or in rate of generation if you please, but where is the difference in *kind*? The whole argument reminds me of the heart specialist who was called on to treat a patient with a broken leg. The doctor treated him for a weak heart because he didn't like to mess with broken bones. I do not mean to ridicule any man who is honestly searching for truth. I am only pointing out that the temptation to interpret observations so as to make them support conclusions

already reached is as dangerous as it is difficult to avoid. Let me hasten to add that I make no pretense of immunity from the hazard.

Now let us return to our explosive model and speculate on still greater distances. If the law of red-shifts does in fact arise from the flight of the galaxies, then at the distance of 5 billion light years the velocity of recession will equal the velocity of light. Any galaxies beyond this limit would have to be fleeing from us at an even greater velocity, and their light would never reach us at all. Thus we have an astronomical horizon beyond which we can never see with any possible kind of instrument.

We have no reason to assume, however, that the earth is located at a point of origin of galactic motion. Were we far removed from such a point, all galaxies would still appear to be receding from us. Assuming such an origin to exist, let us transfer our velocity reference point from the earth to the locale in space where it all started. From that point the universe moves away in all directions with all possible velocities. If the highest velocity of expansion is much less than the velocity of light, the outer boundary of the universe at any one time would be nebulous and diffuse. If, on the other hand, the original energy was such as to produce velocities greater than the velocity of light in the absence of relativistic effects, the presence of those relativistic effects would restrain the velocities to less than the speed of light, and the momentum would be maintained by the corresponding relativistic increase in mass. The result might be a "piling up" of galaxies at the outer boundary of the expanding universe, moving outward as a spherical shell or sort of "shock wave" of light at very nearly, if not exactly, the velocity of light. Such a shell would hardly be visible at the point of origin, but part of it might be visible at points far out from the origin. If this be the case, then, if the earth is sufficiently far removed from the primeval origin, and if telescopes are made capable of seeing far enough, it should be possible to find an increasing density of galaxies in the direction of least distance to the shell or outer boundary. The mathematical model which seems consistent with this concept is described under the title of "curved space," in which the radius of curvature in our universe is said to be 5 billion light years.

Let us now recapitulate the model we have been describing in terms of the origin and evolution of the earth. We start with the phenomenal burst of radiant energy, the solvent for all matter, and call it the birth of our universe. In the first 30 minutes we see all the elementary particles formed and organized into atomic nucleii. Then nothing but cooling and expanding as matter continues to precipitate out of radiation, until all is dark and cold. Then, slowly at first, a great cloud begins to form out of the turbulence, and separate itself from other similarly forming clouds as they all shrink into more dense masses of gas. Then coagulating lumps of liquids and solids begin to form, and little lumps fall into bigger lumps, until certain large ones begin to draw to themselves everything near them. And since the whole cloud was rotating as a part of the general turbulence, all the bodies were also rotating as they formed, the speed of rotation of each body increasing as matter was drawn together in smaller volumes. And as the large bodies grew larger, pressures at their centers increased, with corresponding increase in temperature, until the larger ones became incandescent, shining one by one, all through the galactic system. One of these stars was our sun, and when it "lit up" it illuminated a host of planets with their satellites. One of these planets was the earth, which had coagulated from a little whirlpool of gas within the greater "whirlpool" of the solar system, which in turn was part of the turbulence of the whole galaxy. When the earth reached its maximum temperature, it was too hot to retain water, so all the water of the oceans and the moisture of the soil existed as a dense shroud of steam completely enveloping the earth and continuous right down to the earth's surface. And as the earth cooled, the steam condensed into pools of hot water on the surface. Eventually the moisture in the air dropped below the saturation point, and the fog began to rise, leaving a clear separation between the water surface and the cloud blanket overhead,

much as we see it occasionally now. Then the wet land began to become dry by evaporation, and conditions were favorable for the appearance of vegetation. When vegetation appeared, it sustained itself by reproduction, according to laws of heredity that have been the subject of much study since Mendel's time. The mechanism seems to be that each kind of plant has its seed within itself and reproduces after its kind.

As moisture continued to condense and fall as rain to the earth, the cloud blanket became thinner and ultimately broke up. Then for the first time the sun, moon, and stars were visible on the surface of the earth, and available for telling the time of day and the seasons of the year.

By now we should have a fairly good bird's-eye view of what our universe is and how it got to be that way, according to the most probable modern scientific speculation. Let us turn now to some other cosmologies, pausing first to contrast the scientific atmospheres of past and present. Science to us is a partnership between philosophy and technology. We more familiarly refer to these two aspects today as theory and experiment. This partnership was first seriously joined by Sir Isaac Newton and has been growing with accelerating fruitfulness ever since, particularly as mathematics became increasingly a major tool of both. Before Newton's time, fruitful interactions between the two were rare. When we probe farther back to the Greeks and the Egyptians, the Hebrews and the Babylonians, it was as if neither was aware of the existence of the other, unless to spurn it as a degrading influence on mankind. Even had the thought occurred to form such a partnership, the crude technology of ancient times was a poor match for the philosophical conviction that all natural phenomena were direct actions by conscious gods, whose behavior was as capricious as that of men. It is important that we recognize this when dealing with ancient cosmologies, and maintain a sympathetic attitude as we attempt to place outselves in the position of ancient philosophers.

There are many cosmologies among the mythologies of antiquity. We can not discuss them all, but we will examine two of them. First we will review what has been called the Babylonian Genesis, the *Enuma Elish* ("When above"):

> When above the heaven had not (yet) been named,
> (And) below the earth had not (yet) been called by a name;
> (When) only Apsu privemal, their begetter, (existed),
> (And) mother Ti'amat, who gave birth to them all;
> (When) their waters (still) mingled together,
> (And) no dry land had been formed (and) not (even) a marsh could be seen;
> When none of the gods had been brought into being,
> (When) they had not (yet) been called by (their) names, and
> (their) destinies had not (yet) been fixed;
> Then were the gods created in the midst of them.

The created gods were the sons and grandsons, daughters and granddaughters of Apsu and Ti'amat. But the children always became greater than their parents, and they also became mischievous and annoying, as younger generations sometimes do, until the old grandparents, Apsu and Ti'amat, could not rest. Finally Apsu decided to put an end to the annoyance:

> Apsu opened his mouth
> And said to Ti'amat, the holy (?) one:
> "Their way is annoying to me,
> By day I cannot rest, by night I cannot sleep;
> I will destroy (them) and put an end to their way,
> That silence be established, and then let us rest!"
> When Ti'amat heard this,
> She was wroth and cried out to her husband;
> She cried out and raged furiously, she alone.
> (For) the malice (of Apsu) disturbed her heart.
> "Why should we destroy that which we have brought forth?
> Their way is indeed very annoying, but let us take it good humoredly!"

But Apsu would not be dissuaded, and he plotted to kill his children. But the plot leaked out, and he himself was killed by his own offspring. In ensuing conflicts, Ti'amat was slain by Marduke, who drained out her

blood and let the wind carry it away. He then split her body in two, made the vault of heaven from one half, and from the other half, made the earth. Gods who had supported Ti'amat were enslaved. When they complained of their slavery, the kind-hearted Marduke took their leader's blood and mixed it with clay to make man. Then he assigned to men the task of serving the gods, and set the captive gods free.

This whole account is recorded in cuneiform writing on clay tablets. It consists of seven tablets, totaling over a thousand lines in all, of which approximately 800 or 900 have been recorded and translated. It is representative of the general character of most mythological cosmologies. As one might expect, it bears no real similarity to our own modern cosmology. Under the circumstances, this is not surprising.

Now permit me to review just one more ancient cosmology. This one I will give in an unpublished translation, since the published translations are old, words change their meaning from generation to generation, and recent findings of archeology and philology have added to our concepts of what the originals really meant. This is the cosmology of the ancient Hebrews, and in one form or another may have been nearly contemporaneous with the Babylonian. I paraphrase freely, in the attempt to recapture the original thought as determined by the work of modern scholars, making liberal use of the terminology of modern cosmology.

In beginning, Gods created the heaven and the earth. And the earth was without form, and nebulous, and darkness reigned throughout all space. And the Spirit of God was brooding upon the face of the waters. And God said "Let there be light," and light appeared. And God saw the light, that it was good. And God divided time into periods of light and darkness. And God called the time of light Day, and the time of darkness he called Night. And this completed the first epoch of the creation of the earth.

And God said "Let there be an expanse of clear space in the midst of the waters, and let it divide one part from another." And God made the expanse of clear space above the earth, and divided the waters which were under the clear space from the waters which were above the clear space. And God called the expanse of clear space Heaven. And this ended the second epoch of the creation of the earth.

And God said, "Let all water under the heaven be gathered together into one bed, and let the dry land appear." And it was so. And God said, "Let the earth bring forth grass, the herb yielding seed, and the tree yielding fruit; whose seed was in itself, after his kind." And God saw that it was good. And this ended the third epoch of the creation of the earth.

And God said, "Let there be lights in the expanse of heaven to divide day from night, and for indication of the seasons, days, and years, and let them shine in heaven to give their light on the earth." And God caused to shine on the earth two great lights, the greater for daytime, the lesser for night time. The stars also he made to shine on the earth from the expanse of heaven.

There is more in this Hebrew cosmology with which we will not concern ourselves at this time, since it deals with a quite different realm of science than we are considering. I should point out, however, that the account of the appearance of lights for indicating times and seasons does not make reference to original creation of the lights at this time, but rather the making available of the lights to the earth, such as would occur by a clearing away of the clouds of moisture around the earth.

I think this very cursory review suggests a parallelism between the Hebrew cosmogony and our own. This parallelism is rendered even more remarkable by its striking contrast to the corresponding Babylonian version. It is true that some students of ancient records have attempted to show an extensive parallelism between the Babylonian and the Hebrew cosmogonies. Close scrutiny, however, shows the points of similarity to be purely superficial, and of far less consequence than the overwhelming weight of the contrasts. On the other hand, the amazing consistency between the concepts of Hebrew cosmogony and our own poses a question which science has not answered: How did those ancient Hebrews without aid of telescope, spectrometer, electronics, atomic theory, mathematics, and all the other components of the foundations of modern cosmology, come into possession of the comprehension of prehistoric nature exhibited in their cosmogony?

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Let us remember, please, that the search for the constitution of the world is one of the greatest and noblest problems presented by nature.—G. GALILEI.