Worlds without Number: The Astronomy of Enoch, Abraham, and Moses

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The Universe Beheld by Ancient Prophets

"Now for this cause I know that man is nothing, which thing I never had supposed."[1] So lamented Moses in utter humility after seeing in vision the complexities of the planet Earth and her countless inhabitants. Shortly thereafter Moses was to see once again the earth and her inhabitants ". . . and there was not a particle of which he did not behold. . . and there was not a soul which he beheld not. . . ."[2]Surely this venerable old prophet must have been filled with awe and wonder. Imagine, however, his profound astonishment when, in answer to his plea for an explanation, the Lord revealed himself to Moses and told him of even more wondrous creations. "And worlds without number have I created. . . . For behold, there are many worlds that have passed away by the word of my power. And there are many that now stand, and innumerable are they unto man. . . ."[3]

These startling revelations of other worlds and their inhabitants, of their birth and eventual death were too intriguing for Moses to pass by. The Lord had just warned Moses that he intended to speak of this earth only, but he yielded to Moses' plea to know of the heavens also by declaring, ". . . The heavens they are many, and they cannot be. numbered unto man; but they are numbered unto me, for they are mine. And as one earth shall pass away, and the heavens thereof even so shall another come; and there is no end to my works, neither to my words."[4] Thus, Moses learned that the heavens he beheld, mostly the stars of our own galaxy, would, like the earth, pass away also. Other heavens and earths had already expired. New heavens, star systems with inhabitable planets, would be born in the distant future. The world and the universe are in evolution, ever changing. Birth, life, and death are known to the stars as well as to man. Moses would surely have felt even more insignificant had not the Lord reassured him with his presence and the counsel that "all things are numbered unto me."

Moses was not the first to behold at least a part of the workings of the universe. While conversing with the Lord, centuries earlier, Enoch had stated, "And were it possible that man could number the particles of the earth, yea, millions of earths like this, it would not be a beginning to the number of thy creations; and thy curtains are stretched out still. . . ."[5]

Abraham taught astronomy to the Egyptians, much of which was revealed through the Urim and Thummim. What is evidently a small portion of Abraham's teachings is recorded in the Pearl of Great Price. Evidence indicates, however, that some of Joseph Smith's translations from the rolls of papyrus containing the book of Abraham were not published, presumably because they were not directly relevant to the gospel of Jesus Christ. A most remarkable bit of information comes from other early church literature which quotes from a letter written by W. W. Phelps to William Smith, the Prophet's brother: ". . . and that eternity, agreeably to the records found in the catacombs of Egypt, has been going on in this system (not the world) almost 2,555 millions of years: and to know at the same time that deists, geologists and others are trying to prove that matter must have existed hundreds of thousands of years:—it almost tempts the flesh to fly to God, or muster faith like Enoch to be translated and see and know as we are seen and known!"[6]

The meaning of the parentheses setting off the words (not this world) is not clear; nor is it clear who added them, Brother Phelps, Joseph Smith or Abraham. In any event, it is clear that Abraham's universe was billions of years old. By implication the stars he beheld were not created 6,000 years ago, nor 10,000, but during the preceding two and a half billion years.

Abraham further taught that stars rotate on their axes and revolve in space about other stars according to "set periods" of time, that star and planetary systems had central governing planets or stars, that the star Kolob is nearest the celestial residence, and that it governs the planet Earth.[7] Kolob is said also to be the source of the sun's, energy, although it is not clear whether Abraham taught this or whether it was an Egyptian belief.

Much of what is recorded in the Book of Abraham pertaining to astronomy is difficult to place in modern perspective. The words star and planet are used interchangeably for the same object, but they denote vastly different objects in modern usage. Also, the term "set time" is confusing. The set time of the earth is said to be less than that of the moon, whereas, that of the sun is said to be longer than that of the moon. These set times cannot all refer to the same phenomena. The moon, for example, rotates somewhat more slowly about its axis than does the sun.

The most natural "set time" of the earth is one day, its period of rotation. The natural "set time" of the moon is the lunar month from full moon to full moon, and the natural "set time" of the sun is one year during which it completes its southward excursion. I suspect that these are the set times referred to by Abraham; yet each refers to a different property of motion. One can only speculate about what the "set time" of Kolob means.

In spite of the apparent ambiguity of words, it is clear that Abraham understood much about stellar motions, about star systems and attractions

between stars and planets. He understood that stars require unusual and unknown energy sources. Exactly how much he understood is not clear. Clearly, however, he understood enough that it could have been learned only by revelation.

The concepts of worlds without number, of their birth and death, of the birth, evolution, and death of stars with lifetimes of a few billion years, of stellar rotation and stellar systems are each familiar to the modern astronomer. This modern knowledge has been slow to come, however, and it has been arrived at only after long, tedious research. Scarcely fifty years ago little was known of such matters, or even suspected, by astronomers. A little more than a century ago, when the Pearl of Great Price was published, these concepts would have been regarded as little more than idle, fanciful speculation. It is remarkable, therefore, that they were known by the prophets of old.

Before commenting further on the relationship of modern ideas to the preceding topics, it is of interest to digress somewhat to explore what may have been known of astronomy by contemporaries of Abraham and Moses. Was revelation the only source of such information? Were the general populace ignorant of astronomy, or were they, too, inquiring and thinking about the universe? Were they beginning to understand some of its mysteries? Much of what I will relate is mere speculation. However, there are important clues that suggest biblical man knew much more about the goings on in the heavens than we might suppose. Indeed, it is likely that a common shepherd boy of Abraham's day knew more astronomy, in many respects, that the average man of today's advanced technological world.

Pastoral Astronomy

The history of civilization is filled with folklore of the moon, sun, and stars. The farmer is alerted for frost when the moon is full. He plants by the moon and harvests by the Harvest Moon. A month later he harvests game by the Hunter's Moon under the constellation of Orion the Hunter. In the spring we celebrate Easter on a date set in accordance with the full moon following the spring equinox, a practice stemming from ancient tradition identifying the spring moon with the rejuvenation of earth life following the winter's death-like sleep. These and other traditions have carried over into our day.

We associate summer and winter with the annual excursion of the sun. We are vaguely aware that the moon is periodically full then absent from the night. The stars somehow look different in the winter than in the summer. Aside from these vague associations, however, most of us are oblivious to the regular calendar-like changes of the moon and stars.

How many of our readers have noticed, for example, that the full moon is high in the northern sky during winter and low in the southern sky during summer, just out of phase with the sun? Or, having noted this, how many have also noted that for nine or ten successive years the full moon in the dead of winter moves progressively further north, then for the next nine or ten years swings back to the south, repeating the cycle in approximately 18.6 years?

Chances are that few if any of our readers have noticed these curious, but regular wanderings of the moon. Suppose, however, that you were a shepherd or a farmer living in Abraham's day anxiously watching the deadened pasture of winter or a dwindling food supply. You have no calendar on the wall to keep track of the passage of weeks and months. But you do have a moon whose phases mark off the months and whose position on the horizon at full moon marks off the seasons as well. This, then, is your calendar, reliable, mysterious, and carefully watched.

At rather frequent intervals, as our ancient pastoral ancestors ritually mark off the position of the full moon, an alarming event takes place. The full moon is slowly eaten away by an ominous, invisible *something.* Soon, however, the moon gradually reappears unharmed. The shepherd boy soon notices that this happens only when the moon is full. He hears stories from neighboring villages and travelers that sometimes the sun is similarly eaten away. Perhaps once during his life he sees this awesome, terrifying event. He is profoundly moved by its gravity and its beauty. What if the sun didn't reappear? Surely his life would end. What if some powerful god were doing this to demand a sacrifice?

One of this shepherd boy's friends noted, sometime after the sun had been eclipsed, that it happened at new moon. He learns from others who have experienced or heard of an eclipse of the sun that it too happened at new moon. He now knows two very important facts: the moon is eclipsed at full moon and the sun is eclipsed at new moon.

Sooner or later our ancient shepherd friends decide to appoint an official family moon and sun watcher. Markers are set up to use as reference directions and our official observer begins to chart the daily locations of the sun and moon among the constellations. After a year or two of drawing crude charts, he notices that the paths traced through the stars by the sun and moon apparently cross each other twice each month. The dates and locations of this intersection arouse his curiosity. They bear watching, and perhaps his charts should be a little more accurate.

As he improves his charts and watches the points of intersection, which we call "nodes," he realizes that these points themselves are moving through the stars. Where are they going? Why? His charts are now accurate enough that he knows within a day or two when the crossing will occur. At

each crossing he ponders its meaning and its curious motion. The crossing he anticipates tomorrow night must surely be an unusual one. On that very night the moon will be full. His heightened curiosity is amply justified as he watches the full moon on this special night gradually eaten away by an eclipse. This is an event he will not forget. Will it repeat? What powerful God controls these mysterious nodes? Was the eclipse a warning, a demand for a sacrifice, or what?

Patiently, year after year, our make-believe astronomer keeps his private account of the nodes and their motion. He has now seen several eclipses of the moon, each occurring when the time of the full moon coincided with the crossing of the node. The nodes continue to move slowly on a regular path. Their destination, he knows not.

The astronomer's son takes over his father's job. As an apprentice, he learned all that his father knew. He too is intrigued by the mysterious nodes. The pattern of their motion is soon clear. The nodes move along the same circle through the zodiacal constellations as the sun. They require a little less than nineteen years to complete the circuit as opposed to one year for the sun. This precession of the nodes, he discovers, takes the same time as the swinging of the winter full moon northward and southward on the horizon, both just under nineteen years. He correctly concludes that there must be a connection between the motion of the nodes and the wanderings of the moon on the horizon. (This connection is rather obvious, as our readers will realize after a little thought. Both features of the moon's motion result from a slight inclination of the moon's apparent orbital plane about the earth to the earth's orbital plane about the sun.)

Then one day when our astronomer's charts indicate that the moon is near the node, the remarkable and extraordinary happens. The sun is eclipsed. But what was special about this node? Nothing very unusual, except that it happened at new moon. But new moon had been at the node many times before without an eclipse. As an old man, he ponders the eclipse of the sun, wondering why it had happened only once. From a traveler, he learns of another eclipse of the sun. The reports are too inaccurate, however, and he cannot tell whether it happened on a day when the moon was both new and at the node.

The next few generations of astronomers finally establish that it is true. Eclipses of both the sun and moon occur at the nodes. The nodes obviously exercise a mysterious control over the sun and moon.

Eclipses of the sun are actually more frequent than eclipses of the moon. However, the fact that a given eclipse of the sun is visible from only a small area of the earth, whereas a lunar eclipse is visible from more than half the earth, gives the impression that solar eclipses are extremely rare and that lunar eclipses are common. Partial solar eclipses happen at a given location

about once each hundred years, and total eclipses repeat on the average of only every thousand years. Some thirteen total eclipses Of the sun will cross portions of the United States during the current century. However, seven of these, by chance, pass close to the New England. area and an observer there may conclude that eclipses are really quite frequent.

The circumstances of a given eclipse are repeated rather closely each 18.6-year cycle of the nodes. Many early civilizations discovered this cycle. A rather serious fault with this particular cycle is that the eclipse repeats one-third of a day off schedule. During this time the earth rotates eight hours to the east and the eclipse occurs in a different location from the preceding one. In three such cycles the original eclipse repeats very close to the original location. This cycle requiring approximately 55.8 years to complete was evidently known by some early groups also. It could have been discovered only by several generations of carefully preserved astronomical records. A more thoughtful astronomer than the average undoubtedly began to think about the strange regularity of the sun and moon and the nodes. Each appears to move in a circle, all completing their cycles in different times. The moon has two cycles, one a month long and one nineteen years long. The sun has only one cycle, one year long. Similarly, the nodes have a nineteen-year cycle and a longer cycle of fifty-six years. Eclipses of the moon occur when the full moon crosses the nodes and eclipses of the sun when the new moon crosses the nodes—when the circles intersect. But if this is true, our thoughtful astronomer would realize that he could *predict* when the next eclipse would most likely happen. Eclipses of the sun at any one location are rare indeed, but eclipses of the moon are relatively frequent. He knows that every crossing of the node by the full moon does not produce a lunar eclipse. Still, it's worth a chance. He predicts an eclipse at the next crossing. It happens, and he is now a man of great power. He holds control over eclipses and, in consequence, over his neighbors.

And so it goes; little by little new factors are recognized and eclipse predictions become more and more accurate. All of this has taken hundreds of years to establish and perfect. Undoubtedly many false starts occurred. Wrong clues followed brought disappointments and superstition and mysticism held back progress.

One may imagine that the painstaking record keeping required was too much to expect of early stone-age civilizations. Ancient Chinese records clearly show, however, that in Abraham's era the Chinese were attempting to predict eclipses of the sun.

The great Stonehenge monument in England, built and rebuilt over a period of about 300 years in Moses' era is now believed by many astronomers to be a giant observatory designed to foretell eclipses.[8] Through its carefully placed giant stone arches and lesser stone pillars, it is possible to predict

accurately all eclipses of the sun and moon no matter where they occur on the earth. The original builders of this amazing bronze-age observatory whose construction rivaled in difficulty the great pyramids of Egypt are unknown. At least one legend has them migrating from the Mediterranean peoples. Biblical man was forced to have an interest in astronomy and was far better informed than we are prone to believe. The giant stone eclipse computer built at Stonehenge, however, requires knowledge that is only elementary to that held by Enoch, Abraham and Moses. Those prophets were truly giants of their day, of any day.

Life on Other Worlds

Current concepts of the birth, evolution, and death of stars and star systems have been discussed eloquently in an earlier issue of *BYU Studies* by D. H. McNamara.[9] The picture presented there is in essential harmony with the scriptural picture of a universe in evolution and will not be repeated here. Our own sun is identified by its chemical composition as a second-generation star formed from the debris of earlier stars. It is a common star of a populous class. It appears to be in no way unique. Why, then, should the earth be unique?

Our Milky Way galaxy contains several billion stars much like our sun. Most of these stars may not have a planet similar to that of earth, but millions undoubtedly do. Since science has no way, at present, of knowing exactly what fraction of the stars have planets, we must rely upon intelligent guesses.

In order for a planet to sustain life there are certain conditions which must be met. Consider some of the more obvious ones. The planet must be at such a distance from its star that water remains liquid most of the time. If the planet is too far away, the water will freeze; if it is too dose the water will evaporate. Thus, the planet must have a nearly circular orbit at a proper distance from its star. The gravity at the surface of the planet must not be too large or too small. If it is too large, land masses will not rise above the oceans. Even if they did, animals would not be able to move about erect. If the gravity is too small, the atmosphere will escape into space. The planet we seek must therefore be approximately the size of the earth.

A substantial portion of a life-sustaining planet must be alternately exposed to sunlight and darkness at a reasonable rate; otherwise, the dark side will be unbearably cold. The atmosphere would cool into liquid form and drain off the atmosphere from the hot, exposed side. This means that the planet must have its axis of rotation nearly at right angles to the plane of its orbit. Furthermore, it must rotate at such a rate that the days and nights are of reasonable length.

In other words, for a planet to sustain life similar to that found on earth, it must be similar to the earth in several essential respects. In all, about nine such requirements can be identified. Each requirement decreases the chance of finding such a planet, and nine is a rather large number. Suppose, for example, that the probability of fulfilling any one of these requirements is one in ten; that is, for each star with planets the chance of finding a planet at the proper distance is 1/10, etc. The chance of finding a star with a planet having all nine of the required characteristics would be $(1/10)^9$, or one chance in a billion. Only one star of each billion would have such a planet and only a few would be found in our galaxy.

On the other hand, suppose that each of the requirements imposed on the planet we seek has a probability of occurrence of 1/2. Then one out of each 500 stars will have such a planet, and millions would be found in our galaxy.

At least one of the sun's neighboring stars is known to have planets. The light from the star dims slightly at regular periods and the star periodically wobbles back and forth in the sky. Both effects are produced by a large planet orbiting the star. This planet partially obscures the star as it passes between the earth and its gravitational pull causes the star to move in a small orbit of its own. This single case of two neighboring stars with known planets is clear indication that planets are common companions of stars rather than rare ones.

The remaining requirements for a life-sustaining planet are each believed to occur with a relatively high probability. Our best available evidence indicates that our single galaxy has millions of planets similar to earth. Countless other galaxies exist and, with them, countless other worlds.

In all essential respects, save perhaps one which we discuss in the following section, modern astronomy agrees with the astronomy of the ancient prophets. Those parts of the Book of Abraham that discuss set periods of time for the sun, moon, and planets do not invoke a strong interest from astronomers. Similarly, the control supposedly exerted by Kolob over the earth and the sun is not stated explicitly enough to have physical meaning.

Borrowed Sunlight

The legend accompanying Facsimile No. 1 in the Book of Abraham states that the sun borrows its energy from Kolob. As an astronomer, I do not understand what meaning this might have. The sun generates its own energy from nuclear fusion deep in its interior.[10] The processes are known and understood. The sun has no apparent need to borrow energy from another star, and science knows of no process by which such energy can be borrowed.

The sun does, however, owe its origin and its nuclear fuel to an earlier generation of stars, to a mother cloud of stellar matter. Perhaps this is what

is meant by the Egyptians. It seems more likely, however, that they simply had no basis for understanding nuclear energy and therefore could not describe it.

There is much going on in the universe that is spectacular and challenging to the imagination but cannot be seen with normal eyes. We have discovered these phenomena with huge radio telescopes and with X-ray telescopes flown in satellites. Enoch, Abraham, and Moses talked mostly of things they could see or could visualize. If the more mysterious, "invisible" objects in our universe were revealed to them, they wisely elected to remain silent and avoid meaningless descriptions.

The Unseen Universe of Modern Astronomy

Human eyes are sensitive to just certain colors of light. We see red, yellow, green, and blue with ease, but deep red colors at one end of the spectrum and violet colors at the other end are seen only with difficulty. Obviously by design rather than chance, our eyes are tuned to the colors of the spectrum radiated most intensely by the sun. The earth's atmosphere is "tuned" to transmit most easily just these colors also. Because we see essentially all physical objects around us, in our earthly environment, we are prone to believe that we, in fact, see all that exists. The astronomer is aware, however, that there may be many objects in the universe whose radiations are either too far to the red or too far to the violet to be detected by normal optical means. In the past, he has been forced by circumstances merely to speculate about what might exist in the unseen realm of the heavens. Now, however, our "eyes" have been opened to the rest of the spectrum by modern technology.

The spectacular growth in the field of electronics since the 1940's has opened up the radio end of the spectrum, and huge antennas have since searched the sky for sources of radio signals. Hundreds of new objects have been and are now being discovered. Some appear to be well-behaved, rather ordinary members of the universe. Others are fantastic objects surpassing the most fanciful dreams of the science fiction writers.

Rockets and satellites have, in just the last decade, opened our "eyes" to the ultraviolet, X-ray and y-ray universe. As a result, still another spectacular new universe is unfolding to us. Normal stars and galaxies combine to form a universe of such incomprehensible dimension and of such complex phenomena that we scarcely need more to challenge our imagination. Nevertheless, the challenges are coming hard and fast. What are these new X-ray and radio stars? These are not simple nuclear furnaces, such as the sun; they are as different from the sun as the sun is from the earth. It is not possible to discuss all of the properties of these newly discovered members of our universe in a brief article. Instead we shall choose one of the more bizarre classes of members and discuss a few of their more unusual properties.

Quasars, an abbreviated name for quasi-stellar radio sources, present one of the most exciting challenges in all scientific experience. They have so far defied understanding. Yet they may possibly abound in the universe. Their discovery was made in 1960 when some of the peculiar radio sources were finally matched with faint star-like objects in the night sky. Subsequent analysis of their radiation has yielded an array of startling conclusions. These quasars are true giants of the universe seemingly bent on self-destruction.

The spectrum of the light emitted by quasars is shifted far to the red.[11] Features that occur in the inaccessible ultraviolet region of the spectrum for normal stars and galaxies are shifted into the visual range for quasars. The photons of light have somehow lost much of their energy (as much as two-thirds). We are familiar with the concept of an expanding universe which produces an analogous, but smaller, red shift in the spectral features of distant galaxies. It is tempting, therefore, to explain the red-shift of quasars in the same manner. If that explanation is accurate, then quasars are the most distant members of our universe. The recessional velocities of quasars are amazingly high, up to one-third the velocity of light for the most distant. Light from the most distant quasar discovered thus far has been traveling for more than 2.5 billion years in its journey to the earth. By studying its light we are thus looking back in history to a much earlier epoch in our universe.

If quasars are indeed so distant from us, almost insuperable problems immediately are raised. For some quasars, the light emitted varies in intensity in a periodic way. This enables the astronomer to place a limit on the size of the source producing the light. The period required for a completed cycle of variation in intensity is short, only a few days, for some quasars. Consequently, the quasar itself must be only a few light-days in size, not many times larger than our solar system.

On the other hand, to be seen at all from such a distance, quasars must radiate enormous amounts of energy. Our sun is a fairly average star and our galaxy of approximately 100 billion stars is fairly average also. A single quasar may radiate as much energy as 10,000 galaxies of the brightness of ours, more than is radiated by a hundred million-million suns. It is difficult to imagine processes capable of producing such energy in a relatively small object whose dimensions are only modestly larger than many of the familiar giant stars of our Milky-Way.[12]

The mass of the quasars is estimated to be comparable to that of a small galaxy less than a tenth the mass of the Milky-Way. This corresponds to the mass of many millions of stars. When so much mass is compressed into the relatively small volume required for quasars, it is unstable and tends to collapse under its own intense gravitational attraction. Even the

nuclei of atoms collapse, and theory predicts a catastrophic implosion and annihilation of the matter.

If the quasars are very distant members of our universe, they evidently generate energy far more efficiently than do normal stars. They have less mass and a much smaller size than a normal galaxy, but they radiate far more energy. Throughout the universe we see many giant stars, but always their mass is less than the critical value beyond which gravitational collapse occurs. There seems to be, therefore, a natural limit on the size of a star. However, quasars are much beyond this limit and they still behave as single star-like bodies. Perhaps they really are undergoing this most curious phenomenon of gravitational collapse and the resulting self-destruction. Presumably this would account for the enormous energy they release. The theory of how the energy is produced in this case and how it would escape into space is not at all clear, however.

There is an alternative to placing the quasars at such large distances, and even some observational evidence indicates that they may indeed be much nearer. Quasars occur in pairs somewhat too often to be explained by chance coincidences. This phenomenon of pairing suggests they are associated with galactic systems much nearer to us. If this were true, then the energy they are required to produce is far less than if they are very distant. No special energy sources are required.

The small size required for the quasars remains unchanged, but the estimate of mass is considerably reduced. Gravitational collapse is no longer so catastrophically eminent and it seems possible to construct stable models. Another problem arises, however, and it may be equally as perplexing as the energy generation problem.

If quasars are local, they are very numerous and if they are moving as fast as is indicated by their red shifts they will move out of the local system in relatively short times. Hence, they must be continually replaced. This presents such an enormous energy drain on the local galactic system that spews out the quasars that the galaxies would apparently expend all their energy in a time period that is much shorter than their apparent age. We thus turn from one dilemma to another. Quasars apparently either must generate too much energy to be understood or they drain away impossible amounts of energy from their breeding grounds.

The only competing alternative to interpreting the red shift of the quasars as being due to a high velocity of recession is to assume that the light loses its energy in escaping the strong gravitational field of the quasar. Such an interpretation is possible. However, this theory requires that the quasar be even more massive than suggested above, and it runs into serious difficulty in accounting for other features of the spectrum. Consequently, it has not been widely accepted.

We have touched on only a portion of the amazing properties of quasars. No theory seems adequate to explain them. But then we have known of their existence for only seven years. The picture we have of quasars is evolving rapidly. Perhaps in a few more years we will understand their relationship to the rest of the known universe. Perhaps, also, we will discover still more classes of peculiar objects that challenge our understanding.

Suppose that Enoch, Abraham, or Moses had been shown quasars in revelation. Surely they would have had the wisdom to ponder these strange objects by themselves lest they be considered senile by those to whom they described such unbelievable objects.

Based in part upon talks given by the author at LDS Institutes of Religion at University of Colorado and University of Utah.

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1. Moses 1:10.
2. *Ibid.,* 1:27–28.
3. *Ibid.,* 1:33–35.
4. *Ibid.,* 1:37–38.
5. *Ibid.,* 7:30.
6. *Times and Seasons,* Vol. 5 (1844), p. 758. (cf. Sidney B. Sperry, "Ancient Records Testify in Papyrus and Stone," *Adult Study Course MIA 1938–39* (Independence, Mo.: Press of Zion Publishing and Printing Co., 1938).
7. Abraham 3: 1–9.
8. G. W. Hawkins, *Stonehenge Decoded* (Garden City, N.Y.: Doubleday, 1965). See also F. Hoyle, *Nature,* Vol. 211 (1966), p. 454.
9. D. H. McNamara, "The Origin, Structure, and Evolution of the Stars," *Brigham Young University Studies,* Vol. 8 (Autumn 1967), pp. 7–22.
10. *Ibid.,* p. 15.
11. A given atom, when it is at rest, emits and absorbs radiation at a number of fixed frequencies or colors in the spectrum. These sets of colors are different for each atom and provide the spectroscopist with a set of "fingerprints" by which the atom can be readily identified. The familiar yellow light of a candle, for example, is produced by sodium atoms which are particularly good emitters of yellow light. A trace of copper in the candle may give the flame a greenish-blue color, etc.

If an atom is moving when it absorbs or emits radiation, each color at which it absorbs or emits is shifted by an amount directly related to the atom's velocity. An atom moving toward an observer will have its characteristic color; shifted to the violet, and an atom receding from the observer will have its characteristic color shifted to the red. The faster the motion the greater the change in color. Thus, the radiation from a star (or quasar) moving rapidly away from us will contain the "fingerprints" of many atoms, each displaying a shift to the red.

12. D. H. McNamara, "Stars," pp. 9-10.