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H. Kimball Hansen

CONCERNING ASTRONOMICAL REFERENCES FOUND IN THE SCRIPTURES



WHILE I WAS ATTENDING THE UNIVERSITY OF CALIFORNIA at Berkeley, studying for a PhD in astronomy, my family and I attended church at the Claremont Ward in that city. It soon became known among the ward members what I was studying, and one Sunday after meetings an older member of the ward engaged me in conversation about what I was doing. He soon let me know that, in his opinion, the only legitimate concern for a Mormon astronomer was to find out where Kolob is located. I knew then, as I know now, that that question poses quite a number of difficulties, so I did not really tackle that problem then, nor will it be the subject of the present paper.

My purpose in this paper is to consider the overall question of astronomy (the ancient mother of the sciences) in the scriptures. I will try to lay a background picture of the wide variety of astronomical allusions, statements, references, and knowledge which can be found in our books of scripture. Later presentations in the series will build on this background.

As a starting point, consider this statement in Psalms: “The heavens declare the glory of God; and the firmament sheweth his handiwork” (19:1). This is a concise, deeply moving statement

H. Kimball Hansen is a professor emeritus of physics and astronomy, Brigham Young University.

of a feeling which we have all experienced. Also look at the statements of the Lord to Job concerning creation events: "Where wast thou when I laid the foundations of the earth? . . . Whereupon are the foundations fastened? or who laid the cornerstone thereof; when the morning stars sang together, and all of the sons of God shouted for joy?" (Job 38:4, 6-7). And similarly in the Doctrine and Covenants: "Let the mountains shout for joy, and all ye valleys cry aloud. . . . And let the sun, moon and morning stars sing together, and let all the sons of God shout for joy!" (128:23).

In the passages just presented, the intent seems not to be to convince us that the sun, moon, and stars actually sing together or that mountains actually shout for joy; rather, these statements seem to be intended as literary structures to enlarge our vision of what is being said—to add grandeur and impact, to emphasize the magnificence and importance of the ideas or events depicted. They also have a poetic character that impresses our ears and our minds and that aids us in retaining these things more firmly fixed in our memory. As we continue, we will see that many astronomical references in scripture are of this literary character.

On the other hand, there are also astronomical statements in scripture that relate to factual knowledge, to actual, practical, everyday, hands-on use of natural phenomena and events related to astronomy. In fact our ancestors probably knew the naked-eye sky more intimately and accurately than most of us today simply because they could see the sky and its splendor when they stepped outside at night, whereas we can barely even see the stars in our modern cities and towns because of light pollution.

Perhaps the most remarkable scriptural statement of this factual type is found in Helaman: "And thus, according to his word the earth goeth back, and it appeareth unto man that the sun standeth still; yea and behold, this is so; for surely it is the earth that moveth and not the sun" (12:15). This statement was made just a few years prior to the birth of Christ. For the Nephites to have such knowledge of the rotation of the earth

at that time puts them distinctly ahead of the contemporary Greek astronomers and philosophers, who believed that the earth was stationary at the center of everything. Just how the Nephites became aware of this fact about the earth we do not know, but it serves as an outstanding example of factual scientific knowledge in the scriptural accounts—knowledge in full accord with our present scientific understanding of these things.

To continue this line of thought, let us now look at several other scriptural passages that give indications of a sound understanding of other astronomical or scientific facts. “He answered and said unto them, When it is evening, ye say, It will be fair weather: for the sky is red. And in the morning, It will be foul weather to day: for the sky is red and lowring” (Matthew 16:2–3). This is, of course, an aphorism that we all know today, and it was apparently common knowledge during New Testament times. You might say that this is insignificant, but it demonstrates that by careful observation over many years people can and do learn useful things about the world around them. This particular item shows how observation of an astronomical situation (sunset or sunrise) combined with meteorological conditions (clouds, haze, dust, and so on) provides a useful way of predicting general weather trends. Ancient peoples were just as intelligent as we are today; they were quite capable of observing facts in the world about them and making good use of them.

Job, speaking of God, says, “He stretcheth out the north over the empty place, and hangeth the earth upon nothing” (Job 26:7). The reference here is perhaps to the common observation that there is a region of the northern sky in which the stars never go below the horizon (the circumpolar region). The stars there never appear to touch or rest upon the horizon of the earth; they are always over empty space. And in the last phrase, does the writer of Job mean to say that the earth is not “hanging” from the stars there? Is this an intimation that the writer knew about the true condition of the earth in space, without any support above or beneath it?

God, speaking to Job, says, “Hast thou commanded the morning since thy days; and caused the dayspring to know his place?” (38:12). The modern English New International Version (NIV) translation of this verse states it this way: “Have you ever given orders to the morning, or shown the dawn its place?” (38:12, NIV). This statement seems to refer to the observed motion of the sun during the year (south on the sky in winter, north in summer) and to the way the sunrise point on the horizon tracks this motion. God here asks Job if he is the one who commands this all to occur. For our purpose it is enough to note that the writer of Job was aware of these astronomical facts. It is also relevant to note that Job may have been written at a rather early date.

Now let us look at a couple of other passages: “And it shall come to pass in that day, saith the Lord God, that I will cause the sun to go down at noon, and I will darken the earth in the clear day” (Amos 8:9). “The sun shall be turned into darkness, and the moon into blood, before that great and notable day of the Lord come” (Acts 2:20). It seems rather curious that these descriptions of the sun and moon, commonly given as signs of the coming of the Lord, are also quite accurate descriptions of the appearances of the sun and of the moon during total solar and total lunar eclipses, respectively.

Total lunar eclipses are easy to observe over large areas of the earth, and they actually occur rather frequently, so ancient people were probably well aware of them. The moon being turned to blood corresponds to the coppery appearance that the moon often has during a total lunar eclipse. This color results from the light refracted by the earth’s atmosphere into the otherwise totally dark shadow. The light passing through the earth’s atmosphere is altered both in direction, by refraction, and in color, by absorption. The shorter-wavelength light (violet and blue) is strongly absorbed, while the longer wavelengths (red and orange) pass through with much less attenuation. The light thus cast onto the moon is reddish in color and imparts a dull, coppery appearance to the moon during most lunar eclipses.

Total solar eclipses also occur quite frequently, but because visible totality is limited to rather narrow strips of the earth's surface, they are not commonly seen by most people. However, they are spectacular sights, and accounts of them likely circulated widely among people anciently, just as they do today. Other possibilities sometimes offered to explain a darkened sun and a bloody moon are the possible effects of great amounts of dust and smoke in the earth's atmosphere from numerous natural catastrophes such as volcanic eruptions or from large-scale nuclear warfare.

This series of lectures is meant to be on *science* and religion, not just astronomy alone, so let us here refer to an interesting passage from the book of Ecclesiastes which refers to another scientific topic. "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again" (1:7). Or in the NIV: "All streams flow into the sea, yet the sea is never full. To the place the streams come from, there they return again" (1:7, NIV). This statement reveals that the author of Ecclesiastes was aware of what we now call the water cycle of the earth. The rivers all flow to the sea, then somehow the water gets back to the sources of the rivers to flow into the sea once more. We now know that it is a process of evaporation from the seas, then precipitation as rain or snow on the land to replenish the river sources. The writer of Ecclesiastes understood the basic idea, even though he lacked knowledge of some of the details.

One last example of the factual knowledge type of scriptural statement is the often-quoted sentence from the Creation account in Genesis: "And God made two great lights; the greater light to rule the day, and the lesser light to rule the night: he made the stars also" (1:16). Anyone who has been out at night very much and who has carefully looked for the moon each night has soon realized that there are many nights when the moon is not visible at all during that night. It has apparently fallen down on its job of ruling the night. And continued observation of the situation over a full month or two reveals that the moon is visible in the nighttime sky only

one-half of the time. The other half of the time it is visible in the *daylight* sky along with the sun. Whereas the sun is always visible in the full daylight sky (since the sun actually creates the day, in a sense), the moon, shining only by reflected sunlight and orbiting about the earth, is frequently nearer the sun than the earth is and so presents its shadowed side to our view, sometimes making itself fully invisible thereby. When the moon is thus between the earth and the sun, or near the positions of first and third quarter moons, it also is frequently visible above the horizon for long periods of time during daylight hours.

I believe that the Lord and Moses (the traditional author of Genesis) both fully understood all this, but for the purposes of the Genesis account, the full details were irrelevant. The important things to be stated in that account were the *purposes* for the creation of the earth and of the other bodies that make up the system of which the earth is a part, the existence of those bodies being necessary to make life possible on the earth by giving light and energy to the earth.

We have thus far looked at sufficient examples in scripture where practical astronomy (or science) is found, to establish the fact that such information is there. So let us now turn our attention to other examples where astronomical knowledge serves a largely literary purpose for the writers and prophets involved—places where astronomical knowledge, or figures of speech, are used to add a sense of wonder, exaltation, exhilaration, and grandeur or to make comparisons, similes, and metaphors which clarify, illuminate, emphasize, or enlarge the understanding of the hearer or reader.

We can start with a simple one from the Song of Solomon: “Who is she that looketh forth as the morning, fair as the moon, and clear as the sun, and terrible as an army with banners” (6:10). Or in the NIV: “Who is this that appears like the dawn, fair as the moon, bright as the sun, majestic as the stars in procession” (6:10, NIV). This is also mirrored in the Doctrine and Covenants: “That thy church may come forth out of the wilderness of darkness, and shine forth fair as the

moon, clear as the sun, and terrible as an army with banners” (109:73).

The statement in the Song of Solomon stands by itself and is not closely related to the sentences preceding and following it. It only expresses Solomon’s lofty, elegant, flowery description of his beloved. But the use of the same wording in the Doctrine and Covenants has a much different purpose and effect. It there describes the beauty, clarity, strength, and power of the restoration of the Lord’s Church in modern times and the powerful influence which that restoration will have in preparing God’s people for the momentous events of the latter days.

Then, in another vein, we have a simple natural comparison from the Book of Mormon: “And from this time forth did the Nephites gain no power over the Lamanites, but began to be swept off by them even as a dew before the sun” (Mormon 4:18). This is an effective comparison; the Nephites completely disappeared (or were annihilated), much as the sun causes the dew to quickly evaporate from every blade of grass.

We read from the Book of Mormon in its opening chapter: “And it came to pass that he saw One descending out of the midst of heaven, and he beheld that his luster was above that of the sun at noon-day. And he also saw twelve others following him, and their brightness did exceed that of the stars in the firmament” (1 Nephi 1:9–10). The glory of celestial visitors is nearly always described as brilliant, as if their normal abode were the sun itself. See also the accounts given in Moses 1 and Joseph Smith—History 1:16 in the Pearl of Great Price.

The above two verses from the Book of Mormon are the only ones that I have been able to find that make use of astronomical references of this nature. All other astronomical passages in the Book of Mormon are of a more substantive nature. We have already examined Helaman 12:15 (see also Alma 30:44); the others all refer to the events heralding Christ’s birth and those occurring at his Crucifixion. In contrast, examples of the more literary type are fairly numerous in the Old Testament. Here is a small selection. “Seek him that

maketh the seven stars and Orion, and turneth the shadow of death into the morning, and maketh the day dark with night: . . . The Lord is his name” (Amos 5:8) The NIV gives, “He who made the Pleiades and Orion, who turns blackness into dawn and darkens day into night, . . . the Lord is his name” (Amos 5:8, NIV). Job, in speaking of the powers of God, says, “Which maketh Arcturus, Orion, and Pleiades, and the chambers of the south” (Job 9:9). Compare also the NIV rendering here: “He is the Maker of the Bear and Orion, the Pleiades and the constellations of the south” (Job 9:9, NIV). God, in speaking to Job, asks, “Canst thou bind the sweet influences of Pleiades, or loose the bands of Orion? Canst thou bring forth Mazzaroth in his season? or canst thou guide Arcturus with his sons? Knowest thou the ordinances of heaven? canst thou set the dominion thereof in the earth?” (Job 38:31–33) Again compare with the NIV here: “Can you bind the beautiful Pleiades? Can you loose the cords of Orion? Can you bring forth the constellations in their seasons or lead out the Bear with its cubs? Do you know the laws of the heavens? Can you set up God’s dominion over the earth?” (Job 38:31–33, NIV).

The objects mentioned in these passages—Orion, Pleiades, Arcturus (or the constellation Bootes), and the Bear or Ursa Major (the Big Dipper)—are some of the most prominent and beautiful of celestial objects visible in the northern hemisphere’s sky. Ancient peoples knew these objects well—and the references here hark back to the idea of Psalm 19:1, that “the heavens declare the glory of God; and the firmament sheweth his handywork.”

These passages from Job illustrate a dilemma inherent in this whole subject: one cannot entirely separate astronomical passages in scripture into clean, precise categories. The separation that I have made into practical versus literary is useful, but not exact. And here in these last few passages, though the literary aspects described above are present, there are also some doctrinal implications present that bear upon questions of creation and the powers of God—deep theological subjects. But because of the limited scope and content of

this paper, we will have to leave the deeper questions to some other time.

In a somewhat different context, we have the astronomical comparisons concerning the degrees of glory. For example: “There are also celestial bodies, and bodies terrestrial: but the glory of the celestial is one, and the glory of the terrestrial is another. There is one glory of the sun, and another glory of the moon, and another glory of the stars: for one star differeth from another in glory. So also is the resurrection of the dead” (1 Corinthians 15:40–42).

Section 76 of the Doctrine and Covenants has a long passage (nearly forty verses) concerning these same things. I will abstract here only a few verses which mention astronomical comparisons.

These are they whose bodies are celestial, whose glory is that of the sun, even the glory of God, the highest of all, whose glory the sun in the firmament is written of as being typical.

And again, we saw the terrestrial world. . . .

Wherefore, they are bodies terrestrial, and not bodies celestial, and differ in glory as the moon differs from the sun. . . .

And again we saw the glory of the telestial, which glory is that of the lesser, even as the glory of the stars differs from that of the glory of the moon in the firmament. . . .

But behold, and lo, we saw the glory and the inhabitants of the telestial world, that they were as innumerable as the stars in the firmament of heaven, or as the sand upon the seashore. (D&C 76:70–71, 78, 81, 109)

One could undoubtedly describe how the degrees of glory differ markedly in conditions and glory one from one another without making use of the sun, moon, and stars as metaphors and comparisons, but the use of these metaphors makes the differences immediately, emphatically clear, as well as vivid and concise. The images become definitely fixed in our minds.

Perhaps no other passages serve so well to help us see the literary, descriptive value and power of astronomical ideas in scriptural writings.

Now compare two more scriptural passages with the last sentence of the Doctrine and Covenants passage above. We go to Genesis, where we find God's promise to Abraham: "And he brought him forth abroad, and said, Look now toward the heaven, and tell the stars, if thou be able to number them: and he said unto him, So shall thy seed be" (15:5; note that the word "tell" here means "count"). "That in blessing I will bless thee, and in multiplying I will multiply thy seed as the stars of the heaven, and as the sand which is upon the seashore" (22:17). This promise is echoed in a number of other places.

If we go out into the desert or mountains, far from city lights, so that we see the sky as Abraham saw it outside his tent door, most people would exclaim that the stars one sees are innumerable. But that is simply not the case. It is really quite easy to make an accurate estimate of the total number of stars visible to the naked eye. It only requires that one make a count of the stars visible in a few sample areas of the sky (by looking through the tube from a toilet paper roll, for example) and then make a fairly simple mathematical extrapolation of those counts to what would be visible over the entire sphere of the sky, including the half below the horizon. Over years of teaching, I have had many students do this as an observing project for an astronomy class. The result is that for average eyesight, a maximum of about six thousand stars are visible, perhaps seven thousand for someone with exceptional visual acuity. That number would not be a great many descendants for Abraham to have, though the number of grains of sand upon the seashore is quite another matter. However, if we look at God's statement from a prophetic point of view, he most likely had in mind all those stars which we now know to exist which are too faint because of the vast distances involved to see without telescopic aid. Present astronomical evidence indicates that our Milky Way Galaxy contains some 100 billion (10^{11}) stars and that there is probably that same number of

galaxies visible to us in the universe. That results in there being some 10^{22} stars in total in the universe, which does become comparable with the grains of sand on the seashore.

Up to this point we have considered astronomical or scientific references in a total of twenty-two different scriptural passages. This should be enough to make our main point, that meaningful references to astronomy are found throughout the standard works. And the ones that have been pointed out do not by any means approach the total number there. In a search of the standard works, looking for references to the word “sun” and making use of concordances, indexes, and some computer-aided searching of the scriptural texts, a total of approximately 190 verses were found. Of these, only 13 were in the Book of Mormon, 18 in the Doctrine and Covenants, 30 in the New Testament, and 130 in the Old Testament (35 in Ecclesiastes with its trademark phrase “under the sun”). Five verses in the parallel accounts in Moses and Abraham were dropped since they mostly duplicate ones in Genesis. Of those in the Old Testament, a fairly large fraction of the interesting references are found in the so-called wisdom literature: the books of Job, Psalms, Proverbs, Ecclesiastes, and the Song of Solomon. The word “sun” appears directly in 10 of the 22 references cited, and the sun is alluded to in two others.

REFERENCES TO CALENDAR KEEPING

There remains, however, a very interesting and important aspect of astronomy in the scriptures that we have yet to consider. That is the problem of timekeeping, or more specifically the problem of keeping and regulating an accurate and useful calendar for the ordering of a large community of people such as the Israelites. For the remainder of this discussion, we will turn our attention to that fascinating question and how it was handled in ancient times, particularly what we know about the calendar used by the Israelites of the Old Testament. Entwined with this is the practice of celebrating new moons. Be aware that in the Hebrew calendar, each month begins on the first day of the new moon, with the full moon occurring on

the fourteenth or fifteenth day. (In what follows the italics are mine; it is done solely to highlight this idea of new moons.)

As an introduction to this topic, we will explore the story of David and his serving in the court of King Saul. When David finally became aware of the full depth of Saul's suspicion and enmity and realized that he was no longer safe staying in Saul's presence, he fled. After leaving the palace, he went to Jonathan, Saul's son, and in conversation with him spoke as follows: "And David said unto Jonathan, Behold to morrow is the *new moon*, and I should not fail to sit with the king at meat: but let me go, that I may hide myself in the field" (1 Samuel 20:5). The question here is, why is it that David is expected to eat with King Saul just because it is the new moon? At other places in both the Old and the New Testaments, we read of similar things. For example:

Blow up the trumpet in the *new moon*, in the time appointed, on our solemn feast day. (Psalm 81:3).

And it shall come to pass, that from one *new moon to another*, and from one sabbath to another, shall all flesh come to worship before me, sayeth the Lord. (Isaiah 66:23)

Let no man therefore judge you in meat, or in drink, or in respect of an holyday, or of the *new moon*, or of the sabbath days:

Which are a shadow of things to come. (Colossians 2:16-17)

Note well that in these passages new moons are closely associated with sabbath days and feast days, and this apparently continued into New Testament times. What is the meaning of this, and how did it come about? To find the answer, we need to go to the days of the Israelite Exodus from Egypt. There we find the following things.

The establishment of the Passover.

And ye shall observe the feast of unleavened bread; for in this selfsame day have I brought your armies out of the land of Egypt: therefore shall ye observe this day in your generations by an ordinance for ever.

In the *first month, on the fourteenth day* of the month at even, ye shall eat unleavened bread, until the one and twentieth day of the month at even. (Exodus 12:17-18)

These are the feasts of the Lord, even holy convocations, which ye shall proclaim in their seasons.

In the *fourteenth day of the first month at even* is the Lord's passover.

And on the fifteenth day of the same month is the feast of unleavened bread unto the Lord: seven days ye must eat unleavened bread.

In the *first day* ye shall have an *holy convocation*: ye shall do no servile work therein. (Leviticus 23:4-7)

At this point we should note the following: the Passover was a springtime festival or holy day which occurred near the time of the vernal equinox. It was related to a celebration of the first fruits of the barley harvest (and the beginning of the dry grain harvest season), which occurred in what would be our present month of April. (For the offering of first fruits, see Leviticus 23:10-12.) The Hebrews kept their calendar geared to the agricultural seasons as best they could, since they were essentially a pastoral and agricultural society with need to keep track of proper times for planting, harvesting, lambing, and so forth. The date of Passover (evening of the fourteenth day of the first month, Abib) means that it took place at the time of full moon. It is also well to be aware that another festival instituted during the time of the Exodus, the Feast of Tabernacles, was a fall (harvest) festival occurring on the fifteenth day of the seventh month, which again puts it at a time of full moon and also near the autumnal equinox. Note well also that the

first day of the first month is designated a day of holy convocation, a non-work day.

Establishment of new moon festivals and sacrifices. Just to further emphasize the prevalence of this new moon idea throughout the Old Testament, we will quickly review several other references.

Also in the day of your gladness, and in your solemn days, and in the *beginnings of your months*, ye shall blow with the trumpets over your burnt offerings, and over the sacrifices of your peace offerings; that they may be to you for a memorial before your God. I am the Lord your God. (Numbers 10:10)

And in the *beginnings of your months* ye shall offer a burnt offering unto the Lord; two young bullocks, and one ram, seven lambs of the first year without spot;

. . . This is the burnt offering of every month *throughout the months of the year*. (Numbers 28:11, 14)

He appointed also the king's portion of his substance for the burnt offerings, to wit, for the morning and evening burnt offerings, and the burnt offerings for the sabbaths, and for the *new moons*, and for the set feasts, as it is written in the law of the Lord. (2 Chronicles 31:3)

(In the 1979 Latter-day Saint edition of the Bible these last two passages are cross-referenced to one another on the words "beginnings of your months" and "new moons.")

And continuing on into later Old Testament times:

Likewise the people of the land shall worship at the door of this gate before the Lord in the sabbaths and in the *new moons*.

And the burnt offering that the prince shall offer unto the Lord in the sabbath day shall be six lambs without blemish, and a ram without blemish. . . .

And in the day of the *new moon* it shall be a young bull-ock without blemish, and six lambs, and a ram: they shall be without blemish. (Ezekiel 46:3-4, 6)

They kept also the feast of tabernacles, as it is written, and offered the daily burnt offerings by number, according to the custom, as the duty of every day required; And afterward offered the continual burnt offering, *both of the new moons, and of all the set feasts* of the Lord that were consecrated. (Ezra 3:4-5)

Though there are a fair number of further new moon references that could also be cited, these should be enough to convince us that for some reason, which I confess that I have no inkling of, it was required of the ancient Israelites to keep track of the day of the *new moon* and to celebrate that day, to consider it a *holy day*, and to *offer sacrifices* on that day. This requirement may simply be part of the extensive list of ritual performances which made up much of the Mosaic law, but it raises some perplexing calendrical problems.

Though the details are not explicitly spelled out in the Old Testament, the process of keeping track of new moon days among the Hebrews was probably similar to the practice that was common among neighboring countries and nations of that time, a practice that is known from secular historical records of those nations and from archaeological records recovered from those times. That is, the officials in charge of keeping the calendar in order went out at sunset on the day which they expected to be the first day of a new month to watch for the appearance of the first thin crescent of the moon as it became visible above the western horizon as the sun was setting and dusk began. If they did see the new crescent moon that evening, then that evening was counted as the beginning of the first day of the new month. (Days were then counted as ending and beginning at sunset.) If the crescent was not seen on the expected evening, then they watched for it the next evening. If weather interfered, then they also watched on the

next evening. By the historical times in question, it was well known that the length of the month (time from new moon to new moon) was more than 29 days but less than 30 days—about 29.5 days on average—so if they missed seeing the moon on the expected evening, they could be reasonably sure that it would be visible the following evening, even if weather had been the cause for not seeing it the night before. They also, as much as possible, alternated 29- and 30-day months to keep the average length of the month near 29.5 days.

The interesting point now is that ancient Israel had two rigid calendar requirements to fulfill: First, keep the calendar year in approximate coincidence with the actual year of the seasons, to keep the first day of the year in the springtime and the Passover near the vernal equinox. Second, keep the months in exact coincidence with the phases of the moon—that is, the first day of the month coinciding with the actual day of the new moon and full moon on the 14th or 15th day of the month.

These requirements presented the Israelites with a difficult, vexing, continuing calendar-keeping problem. The sources of this problem are the following astronomical facts: the actual length of the seasonal, solar year is 365.2422 days, and the actual length of the synodic month, the month of the phases, is 29.5306 days. Both are given here to an accuracy of approximately 10 seconds, which is sufficient for our present purposes.

These times just do not fit well with one another. They are, as we say, incommensurable; that is, the larger one is not evenly divisible by the smaller. In the times that we are considering, these periods were probably known only to an accuracy of 365 days for the year and 29.5 days for the month. With these approximate values we have the following result to deal with: twelve lunar months gives $12 \times 29.5 = 354$ days, and $365 \text{ days} - 354 \text{ days} = 11 \text{ days}$. Thus every year the discrepancy between the length of 12 exact lunar months and the length of the solar year, the year of the seasons, amounts to approximately 11 days—more than one-third of a month short. This

means that without any adjustment, the first day of the first month moves 11 days ahead of its original position, near the actual vernal equinox, each year. So to keep it anywhere near its correct position on a continuing basis, after three years an extra, thirteenth month needs to be inserted into the calendar to bring the lunar months back into the desired coincidence with the seasons. (This process of inserting an extra month is called intercalation.) Even with this, a three-day error still exists, and this also accumulates to the point where a thirteenth month sometimes needs to be intercalated after only two years. This whole process needs to be followed continually as long as such a lunisolar calendar is used for time-keeping purposes. It is complicated, but we can be reasonably sure from the evidence in the Old Testament that a calendar of this general type was kept by the Israelites throughout Old Testament times; however, we do not know much about its exact details until postexilic times or later. The current-day Jewish religious calendar is still of this lunisolar type.

But there is also a further problem that the ancients were not fully aware of. The 0.2422 fraction of a day in the year's length amounts to an error of 5.8 hours each year that they were not accounting for, and the 0.0306 fraction of a day for the length of the month similarly amounts to 0.73 hours per month. These may not sound like very big errors, but they accumulate month after month and year after year, and soon a whole-day error has accumulated. This means that from time to time an additional day needs to be intercalated, as well as the thirteenth month. In practice these one-day errors were inadvertently compensated for through the requirement of visually observing the new crescent moon before designating which day begins a new month. Over an extended period of time, the result would be that the months having 30 days would, by a small amount, outnumber those having only 29 days. Thus, as long as empirical designation of new moon days was the practice, these small errors would be somewhat self-adjusting. For more on intercalation, see the appendix in this article.

Below is a table showing the essential features of the Old Testament Jewish calendar, as far as we know the details. Most Bible dictionaries or encyclopedias will show a calendar similar to that shown here. Throughout most of the Old Testament, the months are most frequently referred to by their number, the first month being the one that begins at the vernal equinox. In a few places some are referred to by names which the Israelites apparently borrowed from the Canaanites. Only four of these names are presently known with certainty, and those four names appear on the chart. After the time of the exile, the Babylonian names were commonly used by the Israelites, and seven of the names shown on the calendar chart appear at various places in the Old Testament. They are marked with asterisks.

Probably also beginning after the exile, a second calendar count was used among the Israelites. This count uses the autumn month of Tishri as the first month. This calendar was more used for civil and governmental purposes, while the traditional count beginning with Nisan was principally used for religious and ceremonial purposes. The dating of the religious festivals was done in terms of the latter calendar. One should note that these two calendars were used concurrently; one calendar did not completely replace the other at some point in history. This is somewhat analogous to our using several calendars concurrently today. We have the usual calendar year of the twelve named months; we have fiscal calendars, beginning in July, October, or some other month, for business and governmental purposes; an academic calendar beginning in September is used in our schools; and, here in the West, we keep count of a "water year" beginning in October. We do not have any problems using these multiple calendars for different purposes, and it seems that ancient Israelites had no difficulties using their two calendars concurrently for their different purposes.

ASTRONOMICAL REFERENCES FOUND IN THE SCRIPTURES

OLD TESTAMENT JEWISH CALENDAR

Modern Numbers		Month Names		Modern Equivalents	Agricultural Seasons and Activities
Religious	Civil	Preexilic Canaanite	Postexilic Babylonian		
1	7	Abib	Nisan*	March–April	Spring: Later rains. Begin barley harvest. Flax harvest.
2	8	Ziv (Zif)	Iyyar	April–May	Barley harvest. Dry season begins.
3	9		Sivan*	May–June	Wheat harvest. Early figs ripen.
4	10		Tammuz	June–July	Grape harvest begins. Early grapes
5	11		Ab	July–August	Grapes, figs, and olives ripen. Olive harvest.
6	12		Elul*	August–September	Vintage begins. Dates and summer figs.
7	1	Ethanim	Tishri	September–October	Fall: Early rains, wet season. Begin plowing.
8	2	Bul	Marchesvan	October–November	Plowing. Winter figs. Wheat and barley sowing.
9	3		Chislev* (Kislev)	November–December	Sowing. Some early vineyard pruning.
10	4		Tebeth*	December–January	Rainy winter months. Snow on high ground.
11	5		Shebat*	January–February	New year for trees. Most vineyard pruning.
12	6		Adar*	February–March	Almonds blooming. Citrus fruit harvest.
13	7		Adar Sheni (2nd Adar)		Intercalary month.

CONCLUSION

If we ever reach a point in our discussions of science and religion where we think we have a pretty good match of ideas on both sides of the question, a good resolution of most of the controversies that have bedeviled us, that is when we need to be very cautious and critical of our conclusions. The reason for caution can be stated quite simply. Our experience is that religious ideas remain quite stable over long periods of time, and expectation of any large changes in the near future does not seem great. But, for science, the name of the game is change; there is constantly in the air the question, is there perhaps a better way of explaining or understanding this particular phenomenon or this particular aspect of the world or universe about us? To strive for new knowledge and new ways of understanding the world about us is ongoing and ceaseless. This does not mean that everything we know or even a significant portion of it is completely wrong; it just means that new ways of thinking about things are continually being found, that the boundaries of our knowledge are always expanding, and that new information and new understanding are continually being added to or sometimes replacing the old. And sometimes discoveries are made that cause a very large and sudden change in our view of things, new things and new ideas never even imagined before (for example, quasars and quarks). Over the fifty-some years that I have been seriously interested in astronomy, I have witnessed several such occurrences.

Thus the interface between our knowledge of religion and of science is always an active one, an interface where there are many uncertainties and much speculation. We must be constantly aware of this and not look for or expect any easy answers. We should not be afraid to closely examine this boundary between these two important areas of knowledge, but we should do so always being aware that there are pitfalls to be avoided, on both sides.

APPENDIX

The text and the calendar chart preceding this point were part of an oral presentation given the evening of March 21, 2003. In addition to the comments made above about the process of intercalation in calendar keeping, it seems to me appropriate to give a little more detail about modern knowledge concerning this process

WHY INTERCALATION IS NEEDED

Suppose that over a long period of time we would like to keep a calendar having strictly lunar months (i.e., the months actually coinciding with the visible lunar phases) in approximate synchronization with the seasonal year, the year of 365.2422 days per year. Over three years, an error of about $3 \times 11 = 33$ days accumulates between the lunar calendar and the solar one. If we insert an extra thirteenth month (of 30 days) into the third year, we still have an excess of 3 days left over. This, with the 11-day error accumulating each succeeding year, will soon add up to the need to insert (intercalate) another thirteenth month into a year. As a continuing process we need to intercalate a thirteenth month every third (or second) year and do so indefinitely. This intercalation procedure is the basis of a lunisolar calendar, which is what the Old Testament Jewish calendar was.

THE METONIC CYCLE

Although the idea of intercalation was known and used in ancient calendars long before the year 380 BC, at about that time a Greek astronomer named Meton (as well as astronomers in Babylonia) became aware of a very amazing fact, as follows: $19 \times 365 = 6935$ days, and $235 \times 29.5 = 6932.5$ days. Thus 235 months (using ancient values for month and year lengths) is equal to 19 years within a difference of only 2.5 days. Using modern data for month and year lengths, the difference is only 0.0892 day, which is equal to 2 hours, 8 minutes, and 27 seconds. Truly astounding!

But for a calendar having strict lunar months we still need to use, as our foundation, the average number 29.5 days per month—that is, alternating 29- and 30-day months. For one Metonic cycle, $19 \times 12 \times 29.5 = 6726$ days, and $19 \times 365.2422 = 6939.6018$ days. The difference is 213.6018 days, which is equivalent to 7.2407 months. Hence seven intercalary months need to be inserted during each 19-year period. This is usually done in the years three, six, eight, eleven, fourteen, seventeen, and nineteen of the 19-year Metonic cycle. (The modern Jewish religious calendar makes use of this pattern.) But error still remains. First, eighteen additional days must be intercalated over 95 years (five 19-year cycles), or one day about every five years, and this pattern must be continued indefinitely. These extra days can be added to months that would ordinarily be 29-day months in the regular alternation. Second, a remaining small discrepancy accumulates to another additional day after 209 years (11 metonic cycles), requiring a 1-day adjustment then and continuing at 209-year intervals thereafter. With this the resulting calendar keeps reasonably accurate synchronization with both lunar phases and the vernal equinox for a very long time period. It only needs an additional, arbitrary 1-day adjustment after something on the order of 2,700 years.

The scheme described in the preceding paragraph does not correspond in full detail to any actual lunisolar calendar in present use or any that I know of from the past. It is just a brief mathematical example of the problems posed and one way of taking account of them. Please do not consider it of any more value than that.

By comparison, the Islamic calendar, instituted by Muhammad in AD 622 and continuing in use today for religious purposes in Islamic cultures, is a strictly lunar calendar. That is, 12 lunar months constitute one complete Islamic year. There is no attempt to keep this lunar year in step with the seasonal, solar year. Hence the months of this Islamic calendar gradually drift through the seasons, each month recurring about 11 days earlier among the seasons each succeeding year,

completing a full cycle in about 33 years. This is why the celebration of Ramadan (the Islamic month of fasting) occurs at different seasons as the years pass by. The months alternate 29 and 30 days as already described above. In a 30-year cycle, nineteen years have 354 days, and eleven have 355 days. This way of intercalating extra days keeps the lunar calendar in very close coincidence with the visible lunar phases over a long period. Nearly twenty-six hundred years will elapse before further adjustment is needed.

Our present-day calendar (the Gregorian calendar), which is used for civil purposes by virtually all nations today, is not a lunisolar calendar. It is a strictly solar calendar in which the year is kept in accurate coincidence with the vernal equinox by use of the addition of a leap day every fourth year—with that leap day being omitted from three leap years during each four hundred years. They are dropped from those century years which are not divisible by four hundred. No attention is paid to keeping the calendar months in coincidence with the lunar phases. The visible lunar phases thus drift through the months, and we do not use them for any significant calendrical or religious purpose.