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THE JEWISH CALENDAR

by

Avraham bar Hiyya

Part I

Translated with a Commentary

and Annotations

by

Mordecai Miller

Thesis submitted in partial fulfillment of the requirements for the Degree of Master of Arts in Hebrew Letters and Ordination.

Hebrew Union College - Jewish Institute of Religion

1974

Referee, Prof. Dr. Ben Zion Wacholder

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Note: SI refers to our text Sepher haIbbur; ed. Herschell Filipowski; London, 1851

PREFACE AND DIGEST

Avraham bar Hiyya (b. Soria, 1065 - d. Provence, 1143), also known as ha-Sephardi (the Spaniard), ha-Nassi (the Prince), Abraham Judaeus and Savasorda, was one of the outstanding products of Spanish-Jewish culture of the period. He was able to draw from both the Jewish and secular-scientific sources, and integrate what he had acquired into a workable personal philosophy. bar Hiyya's primary contribution was his original compositions on scientific and philosophical subjects, which he wrote in lucid Hebrew. This practice was unusual in a time when most Spanish Jewish writers chose to compose their scientific works in Arabic. This practice of bar Hiyya's meant that the hitherto untouched field of "secular" science was now laid open to those Jews of France who had, until then, only immersed themselves in rabbinic literature.

The Sepher ha'Ibbur is a clear non-technical explanation of all the details that concern the Jewish calendar. Its simplicity, yet comprehensiveness, would imply that it is a work intended both for the beginner who wishes to acquaint himself fully with the mechanics of Jewish calendation, and the scholar who wishes to deepen his acquired knowledge. In fact, many subsequent authors availed themselves of the information it provided, including Maimonides in his Laws Concerning the Sanctification of

the New Moon (ch.10:1), and the author of a later astronomical work, the Yesod Olam, Isaac Israeli.

The book is divided into three essays. The first, which is the subject of our present work, deals with basic astronomical concepts which are necessary in order to gain a clear conception of the workings of the calendar. We start off with a description of the various "climates" of the earth's populated area and progress to a discussion of the division of the heavens, which enable us to locate any particular part of them, and measure their movement and the movement of the planets within them. The latter two factors are what are basically behind the science of calendation. The discussion then centres on the different configurations of the heavens as one changes latitude, and the difference in time-zones as one changes longitude. Some conclusions from the last two features, viz. measurement of length and breadth of countries, are then discussed. The next basic part deals with the independent movement of the sun and moon. These are the two bodies which give us our years and months respectively, and thus it is important to understand their basic movements. Finally, the last three chapters deal with the day, its definition, its beginning and its divisions. There is also a discussion here on the location, according to which, the astronomical calculations are to be based and the original starting point of the luminaries. The essay closes with a discussion of

basic astrology, viz. the planets which govern the days and nights of the week.

The second essay deals with the rules of calendation and how the lunar months and solar years are aligned. The last essay deals with the solstices and equinoxes of the solar year, the Sabbatical and Jubilee years and a comparison between the secular (Christian), and Jewish calendars, and how dates in one can be translated into the other.

The work, as a whole, displays but a part of the tremendous acumen of the author. Although some of the theories in the first part have been superseded, many of the descriptions remain as accurate today as they were in those days. Perhaps such a work, which combines a scientific approach with a deep-rooted piety, can still serve as an inspiration to us to try and find a path which can combine an understanding of today's scientific world, with Torah.

COMMENTARY TO THE INTRODUCTION.

In the preamble to his treatise, Abraham bar Hiyya explains the reason for his choice of arrangement. But for such an explanation, we may have thought that the whole first essay, which deals with aspects of astronomy, were superfluous.

What we have to deal with, bar Hiyya explains, is a series of interrelated phenomena: the earth's shape, the movement of the celestial sphere and the sun and moon. bar Hiyya, therefore, starts with basic concepts, such as the earth's shape and gradually works up to a fairly sophisticated notion of "day". At this stage, the actual mechanics of calendation can be introduced, as they are, in the second essay.

The point of the introduction, then, is that the workings of a calendar can in no way be fully understood, without presupposing some knowledge of basic astronomy and time measurement. The purpose of the first essay is to supply the reader with such background material.

We must ask ourselves why bar Hiyya goes to such great lengths in expounding the verse in Genesis (1:14),

> "Let there be luminaries in the firmament of the sky to make a distinction between the day and the night; they shall serve for signs for the festivals, for days and years."

Two reasons can be evinced, one for each of the two expositions that bar Hiyya makes.

Firstly, bar Hiyya wishes to show that the basic ideas of calendation, which prima facie are derived from secular sources, are in fact set out in the Bible, and that they are linked to the creation of the world, i.e. God had the calendar built into His creation plan. Since the Jewish calendar is made up of weeks/sabbaths, months/new moons and years/sabbatical and jubilee years, the first analysis of the verse extracts these concepts.

The second analysis tries to cope with a different problem. In the actual construction of the calendar, the lunar months and solar years have to be brought into alignment, this necessitates a process called intercalation. This is the addition of a thirteenth month to the year, and the assigning to certain months 29 instead of 30 days and vice-versa. Now, if God had intended the luminaries to serve as signs for the setting up of the Jewish calendar, then why did He not create them so that aligning the lunar and solar year would not involve such a complex process? The second analysis (p. 8f.) tries to show, though unconvincingly, that even though the process may be complicated, God had already hinted at the process by which the lunar and solar years could be aligned, viz. through the Metonic Cycle.

THE INTRODUCTION

With the help of the Eternal, I shall begin this treatise. It is written:

> " The LORD founded the earth with wisdom; He directs the heavens with understanding." [1]

May the name of the Holy One Blessed Be He be praised and extolled, in that He created the heights and depths [2] corresponding to above and below; making them interdependent so that each one would elucidate the other, and one who understands the nature of the first, can understand the second.

Indeed, one who knows the characteristics of the heights, immediately can comprehend the characteristics of the depths. Conversely, by understanding that which concerns the depths, that which concerns the heights becomes explicable. In a similar way, in the case of any two phenomena which are interdependent and causally connected, each is linked to the next in order to elucidate it, and participates with it in the definition of the matter.

Thus we find that Scripture likewise makes the creation of the heavens and the earth linked to one another: at times the one precedes and at times it follows. One verse states: "The LORD founded the earth with wisdom; He directs

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1. Prov. 3:19

2. Heights and depths, i.e. heaven and earth.

the heavens with understanding." In other words, He founded the earth with wisdom, and afterwards directs the heavens with understanding. But another verse states: " I alone stretched out the heavens; spread abroad the earth by Myself." [3] i.e. He first stretched out the heavens and afterwards spread out the earth. This is to show you that the existence of one exists for the sake of the other, and a person can only understand one by the creation of the other.

If this is the case with regard to their creation, all the more so concerning a case that is a derivative of them both. For example, a person who wishes to explain the phenomena of days, months and years will necessarily have to explain the creation of the heavens and the earth and the movement of the sphere.[4] Only after this can he explain days and months, since the precise length of the month is determined solely by the movement of the sun and moon, and the movement of the sun and moon follows the motion of the sphere in its revolution. From the motion

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3. Isaiah 44:24

4. sphere. i.e. celestial sphere.

of the sphere with the sun, one can explain days and nights. The upshot of the matter is that measurement of time simply corresponds to the amount of spherical movement. Thus "Let there be luminaries in the firmament of the sky to make a distinction between the day and the night." [5] The luminaries only make a distinction between day and night through the rotation of the sphere. For day is the time [6] during which the sun rises over the earth and is visible to the earth's inhabitants and the stars cannot be seen; while night is the time that the sun goes under the earth and is hidden from the earth's inhabitants and the stars appear. From their continuous return and motion [7] they shall become signs for festivals, days and years corresponding to sabbaths, new moons, sabbatical and jubilee years; as it is written:

> "They shall serve for signs for the festivals; for days and years." [5]

---

5. Gen. 1:14

6. The fact that the sun goes round the earth already gives us a clue that bar Hiyya was aware that the earth was spherical. We shall see a statement by him to this effect in the opening sentence of the first gate (p.14)

7. This is precisely what makes the science of calendation possible. It is through the exact measurement of the periods involved e.g. the mean lunar month, the tropical (i.e. solar) year in terms of days and fractions of a day, (which are also themselves periods of time) that we can set up a calendar in which dates of festivals are fixed and longer periods such as the Sabbatical and Jubilee cycles can be estimated.

"Signs" here, commonly means "Sabbaths", as is proved from the verse "Nevertheless, you must keep My Sabbaths, for this is a sign between Me and you..." [8]

"Festivals" are "new moons", proved by "All these you shall offer to the LORD at your festivals..." [9] You will find the New Moon Sacrifice mentioned at the beginning of the paragraph following the one dealing with Sabbaths. Thus you can infer that the new moon is the principal for the festivals. [10] Moreover, all festivals depend on certain days of the month. The new moon is the basis for them all and through it they all become assigned. It is also stated "He made the yareah for festivals, the sun knows its circuit." [11] Yareah means moon as it is stated "to the sun or the yareah." [12] Thus you find that the Holy One, Blessed Be He, makes the festival in its particular new moon, just

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8. Ex. 31:13.

9. Num. 29:39.

10. Heb. ראש למועדים
The new moon was the first day of the new month. Consequently, it was only through knowing on what day the new moon would appear that the month could be determined, and the festival celebrated on the correct day. This is the main historical reason for the introduction of the "two days" of a festival outside of the land of Israel.

11. Ps. 104:19.

12. Deut. 17:3.

as there was originally at each new moon.[13] In all these instances, new moons are called festivals.

"And for days", these are "a year" or "years". That the word "days" refers to "years" can be deduced from the verse "...the redemption period shall be days."[14] While the next verse states "If it is not redeemed before a full year has elapsed..."[15]

That it refers to "years" can also be inferred from the verse "And it came to pass, that in the process of time, at the end of two days..."[16]

In connection with "days", we mentioned that they refer to Sabbatical years, since Sabbatical years are really a number of years, as you can see from the verses "Six years you may sow your field and six years you may prune your vineyard and gather in the yield."

"But in the seventh you shall let it rest and lie fallow." [17] You know that up to the Sabbatical year they count year by year up to six years, and when they get to

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13. bar Hiyya seems to be referring to the Biblical festival mentioned in I Sam. 20:18-22. Note verses 24 and 35, where it is clear that "new moon" and "festival are synonymous.

14. Lev. 25:29.

15. ibid. v.30.

16. II Chron. 21:19.

17. Lev. 25:3 and Ex. 23:11, respectively.

the seventh year, they declare a Sabbatical year.

"and years": these are "Jubilee years", because they used to count them off in periods of seven years as scripture states: "You shall count off seven sabbaths of years - seven times seven years..."[18] Every seven years is called one week (shavuah) or one sabbath. We have shown you that "days" here is one year, that is, one seventh of the Sabbatical period. Seven years make up one Sabbatical cycle, which is one seventh of a Jubilee year.

Scripture states thusly: "they shall serve for signs for the festivals; for days ..."[19] "For" is placed before each word to inform you that one is distinct from the next. At the end of this verse it states "for days and years", and does not separate them by using "for", so as to let you know that one is the same thing as the other, and there is only a quantitative difference between them.

But you may also expound this verse in a different way and say that "signs" are "Sabbaths", as we said above; "festivals" correspond to "new moons" and "days" correspond to "the lunar year". This was not called simply "year", since it is not a complete year. Sometimes it is an ordinary year with twelve months, and sometimes it is embolismic,

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18. Lev. 25:8 and not 32:8 as cited by Filipowski.(SI p.4)

19. Gen. 1:14. See p.5; The original has a "ל" before each of these words.

with thirteen months. "Years" correspond to "nineteen year cycles"(ie."Metonic cycles."tr. note.) by which the tropical and lunar years are equalized. You will find that all these periods of time depend on the celestial of day and night in order to be reckoned, whether Sabbatical cycles and Jubilees, or lunar years and nineteen year cycles. Day and night, in turn, depend on the movement of the celestial sphere, by which they can be counted.

Since I intend to explain the method of calculating months and years, which we are obligated by the Torah to know, so as to sanctify the new moons in their proper time and so keep the festivals which accompany them according to halacha [20], I first had to explain the behavior of day and night, since the months and years are reckoned through them. Since I found need to explain their nature, I decided to explain a little of the formation of the heavens and the earth, and the sphere's rotation and cycle - as will be clarified in the chapter dealing with the measurement of day and night.

I had to mention all this at the very start, so that no one should think that I am bringing something irrelevant to the explanation of this subject, but will realise that everything was necessitated by the need to elucidate it.

If I had found such a treatise in France, in Hebrew,

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20. The accepted Jewish religious law.

which completely explained the whole subject together with all the necessary proofs, I would not have gone to all this trouble. Similarly, if I had found the need filled in the treatises which I acquired from the books in Spain, written in Arabic, I would have translated them in Hebrew as best I could, and would not have added a thing of my own, since I do not consider myself worthy of standing and talking before the great.

How can I make myself worthy enough to explain or publish a thing? Only because I did not find anything else on it, I was obliged against my will, not for my welfare, to take this course because great men and wise, ordered me to explain this subject as best I could. I would not ignore what they said, nor evade their decree; just as our rabbis, of blessed memory, said, "I am not a priest, but if my friends said to me:'Go to the altar, I would go.'"[21]

Now, if it is obligatory according to the rabbis that a man accept the words of his fellow, how much the more so the words of his rabbis and sages, seeing that it is a commandment of the Torah that one listen to them and that one who argues with them is deserving of death. I had to explain and elaborate all of the things which they forced me to do, to go beyond my ability and put myself in an unmerited position of honour. Perhaps my reader will judge my

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21. Cf. b.Shabbat 118b.

explanation sympathetically. In this way, I can be reassured enough to attain the degree to which they elevated me and can begin with the subject matter of this book.

Let me say, with regard to this treatise, for all the reasons which I have enumerated in the introduction, that it is necessary to divide it into three essays.

The first essay: An explanation of all the factors which one needs to explain at the outset, before the treatise proper, so as to elucidate its details and to add substance for the reader.

The second essay: The measurement of the length of the months, the lunar year, the calculation of the conjunctions and the determination of the festivals and everything dependent on this.

The third essay: The solar year, the solstices and equinoxes, the calculation of the Sabbatical and Jubilee cycles, and all that depend on them, the calculation of the years of the Gentiles and the times of their festivals and anything of the like.

So I will begin, with God's help, the first essay, and may the LORD Almighty help me in His abundant mercy, and lead me in the right path: for He gives wisdom; from His mouth comes knowledge and understanding.[22]

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22. Prov. 2:6.

COMMENTARY TO THE FIRST GATE.

We have noted in the introduction (p.3) that the "heights and depths are interdependent." Our first gate thus deals with the "depths" which are probably what would be most familiar to the reader. The earth, in being considered the centre of the universe, was also conceived of as stationary, with the heavens and planets rotating/revolving around it.

bar Hiyya explains some basic geography, which will later serve to elucidate the discussion in the forthcoming gates concerning changes of the day's length, temperature and time: the interdependency of the heavens and the earth!

Note how he skillfully uses verses from Genesis 1 to show that the Bible predates secular learning - as long as one knows how to extract such information.

This gate is an interesting combination of truth and speculation: the seasons are, indeed, reversed in the northern and southern hemispheres, and it is quite likely that the length of the longest day at the latitudes mentioned are, in fact, what bar Hiyya claims them to be; but land and sea are not equal in dimension, and the populated area does stretch further than 16° south of the equator.

The combination expresses how difficult it was to

distinguish, in those times, (and some might well say, even in these times!) the difference between fancy theorizing and scientific reasoning.

THE FIRST GATE

The shape of the earth and the dimensions of the inhabited part.

Know that all the scholars who delved into this matter all agreed that the earth is round[1] like a ball or a cylinder.[2] The waters of the great sea cover one half. Consequently, half of the earth is land, called the inhabited part (ecumene), while the other half is submerged in the ocean where there is no settlement. The other seas within the half which is land are like the islands in the water. You can deduce that the portion of the earth which is land is the same dimension as that which is water.[3]

Proof from the Torah:"Let the waters be gathered from under the heavens to one side and let the dry land appear - and it was so," [4] when the waters gathered to one

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1. The Greeks at least as early as Aristotle (384 -322 B.C.) himself, were aware that the earth was round. Aristotle cited two proofs: 1. The shadow cast by the earth during a lunar eclipse is always round; only a spherical object can do this. 2. Travelers going north see different stars appearing over the northern horizon and disappearing over the southern. bar Hiyya goes into great detail over this latter phenomenon. (cf. Third Gate).

2. The Hebrew in the text is כנורת , which ben Yehuda (Thesaurus Totius Hebraitatis. Jerusalem, 1948) gives as equivalent to "lyre". (Heb. כנור) The use of this word is somewhat obscure. The only other reference ben Yehuda cites is תחכמוני ע"י ה"ת חריזי. However, the word in the text was apparently a printer's error (cf. 122 SI) and should read "צנורת " -"cylinder".

3. Actually 3/5ths of the earth's surface is water.

4. Gen. 1:9.

side, the dry land appeared on the other. The one has the same dimension as the other: they were divided up according to one standard. Thus "God called the dry land, earth; and the body of waters He called seas." [5]

Concerning everything in the creation epic which God divided into two, assigning each a name, you find that the dimension of one is the same as the other, as "God called the light, day, and the darkness He called night."[6]

Just as the length of daytime is equal to that of night, so the dimension of the body of waters is equal to that of the dry land. And just as there are places where daytime exceeds the night, and places where the night exceeds the day, and in comparing the excess of one with the other, both equal out;[7] so there are places on earth where the dry land protrudes, and places where the sea intrudes, but when you compare one with the other, both equal out. This makes it clear to you that half the earth is land and half of it is water, and I do not have to bring any further proof from

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5. Gen. 1:10.

6. ibid. 1:5.

7. What bar Hiyya seems to be referring to is if, for example, we take the case of some place situated 16° north. During the winter solstice, their day would be 11 hours long. (cf. p.18 .) However, at 16° south, on the same day, their day would be 13 hours long. Thus the average length of daylight in both places is $\frac{11 + 13}{2}$ = 12 hours, which is exactly half a 24 hour day. The same result would apply if we chose a different latitude and/or different day of the year.

external science.

The dry part called land, is divided into four parts by two imaginary lines.[8] One goes from east to west. This line runs across the length of the earth[9] and is called the equator. The second goes from north to south and this line runs across the breadth of the earth and is called the meridian. Of these four parts, two are northerly: one north-east, the other north-west. Similarly, in the south there are two parts: one south-east and the other south-west.

Not all these parts are inhabited. The inhabited part stretches over the length of the earth on the line starting from the east stretching all the way west. It does not, however, stretch over the whole breadth, but begins with the line of the length,[10] stretching northward to a distance of 66° in 90°. From here on there is no settlement, on account of the cold. Similarly, it begins at the line of length

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8. Lit. "lines which a man construes of as dividing..."

9. One might suppose that if the earth is spherical, it would make no sense to talk about "length" and "breadth". The reason is given in the Fifth Gate. The population is spread out along the whole equator that runs across the land (180°) while it does not spread out over more than 82° of the meridian. Thus, though the meridian is 180° too, for practical purposes we can refer to it as the breadth of the earth. bar Hiyya appears to indicate a specific meridian as being the line of breadth - we simply call this "the meridian" or the "terrestrial meridian".

10. ie. the equator.

and extends southward only to a width of 16° of 90°. From here on there is no settlement on account of the heat.

Hence the settlement widthwise is 82° in 180°, from the northern extremity to the southern. This whole 82° is settled lengthwise from east to west. Thus those who espouse secular learning say only 1/4th of the earth is settled, since half the earth is under the sea and with regard to the other half, half is desolate and wasteland, and the other half is populated.

Of this inhabited area, 16° south of the equator is populated by the sons of Ham, whom scripture cursed.[11] Their situation is opposite in all respects from that of the inhabitants of the northern hemisphere, since our warm days are their cold ones,[12] while our cold days are their warm ones. Similarly, as our days lengthen, their days shorten; our long nights are their short ones, and our short ones their long ones. Consequently, men of this science left them alone and did not go to the trouble of explaining the characteristics of their lands.[13]

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11. see Gen. 9:20 - 25. (cf. Gen. 10:6)

12. Despite the fact that the heliocentric theory which accounts for the seasons (due to the tilt in the earth's axis), was not held by bar Hiyya, as we can see from the Sixth Gate, his description of the phenomena is accurate. What he means to say here is that the seasons are reversed from the northern hemisphere in the southern: spring = autumn and summer = winter and vice versa.

13. The phenomena were simply the converse of the north.

The populated part of the northern area is 66° (broad) which scholars divided into seven parts. They called each one of them an aklim, "climate" in Arabic. These are populated by the remaining 70 designated nations[14] in the world. Some of them live on the earth's equator, which is the line that runs lengthwise. Their days and nights are always of equal length.[15] On no day of the year does one exceed the other. This is the situation of all those who live at the equator, from furthest east to furthest west.

Those who live a distance of 16° from the equator, which is the middle of the first climate; their longest day, during the solstice in Tammuz is 13 hours, and their shortest day is 11 hours, during the solstice in Tebheth.

Those who live a distance of 24° from the equator, the middle of the second climate, have a longest day of $13\frac{1}{2}$ hours and a shortest day of $10\frac{1}{2}$ hours

Those who live 30° away from the equator are the inhabitants of the third climate. Their longest day is 14

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14. These are the offspring of Noah's three sons of whom Gen. 10:32 states:

> "These are the families of the sons of Noah, after their generations, in their nations; and of these were the nations divided in the earth after the flood."

There are in fact 70 names of offspring of the three sons listed in Gen. 10: 2 - 30.

15. Further explained in Gate 3, p. 49 as are the differences in the day's length at other latitudes.

hours and their shortest day is 10 hours.

The fourth climate is 36° away from the equator. The longest day is $14\frac{1}{2}$ hours and the shortest is $9\frac{1}{2}$.

Those who live a distance of 42° away from the equator are the inhabitants of the 5th climate. Their longest day is 15 hours and the shortest 9 hours.

The sixth climate is 48° from the equator. Their longest day is $15\frac{1}{2}$ hours and the shortest $8\frac{1}{2}$.

The seventh climate is 54°. Their longest day is 16 hours and the shortest 8 hours.

Those who live a distance of 66° away from the equator, i.e. the limits of the inhabited are of the northern hemisphere have a longest day of 24 hours (a whole day!), and there is no night. Their shortest day is a complete night and there is no daylight.

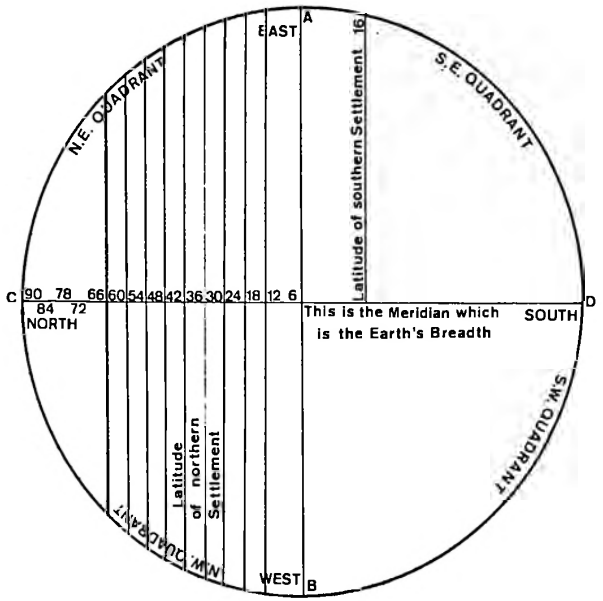
Consequently, in all cases where the longest day measures x amount, one can infer the measure of the corresponding night is the same as its shortest day, so that they both add up to 24 hours, which is the length of one full day. For example, if the longest day is 16 hours, its corresponding night is 8 hours and their sum is always 24 hours. This situation occurs at the Tammuz solstice. But in the solstice of Tebheth, exactly the reverse takes place, the night is long and the day is short. During the Nissan and Tishre equinoxes, the day and night are equal everywhere.

Here I have drawn a circular figure for you, and set down all the lines which divide the earth, so that you can

actually see so as to consider it better.

I wrote on the figure at the east point "A", the north point "C", the west "B", and the south "D". The arc from A to C is the north-east quadrant; the arc from C to B, the north-west quadrant; and from B to D the south-west quadrant and from D to A, the south-east quadrant.

I divided each of these four quadrants into 15 parts.[16] I wrote in the first part 6, the second 12, in that order, until the text reached the 15th section which went up to 90°. This is the number of degrees which make up each quadrant.



16. Although the figure is only divided into fifteen parts for the northern hemisphere, the same division for the southern hemisphere can be inferred.

I started to write in each quadrant: "East" in the extremity of the eastern parts, and "West" in the extremity of the western parts. For the lands which extend from them towards the north and south, I put seven lines northward corresponding to the seven populated climates in the North. Each climate is placed according to its distance from the equator. Thus I placed a line at the extremity of the populated area in the north and a line at the extremity of the southern populated area.

You will find in this figure that the equator is the line which has at its extremities points A and B; the one in the east and the other in the west. C and D are at the extremities of the meridian, one in the north and the other in the south.

In this way the figure is drawn up.

We have sufficiently explained the shape of the earth and we will start to explain a little the shape of the celestial sphere and its motion.

COMMENTARY ON THE SECOND GATE

The heavens appear to us as a great sphere surrounding the earth. Imagine the earth as a transparent sphere with the lines of latitude and longitude drawn on it. Next, imagine projecting these lines from the earth's centre onto the "celestial canopy." It is now possible to work out a reference system for the heavens.

1. The Celestial Poles. (see p.32)

These are the points which are imaginary intersections of projection of the earth's axis and the celestial sphere.

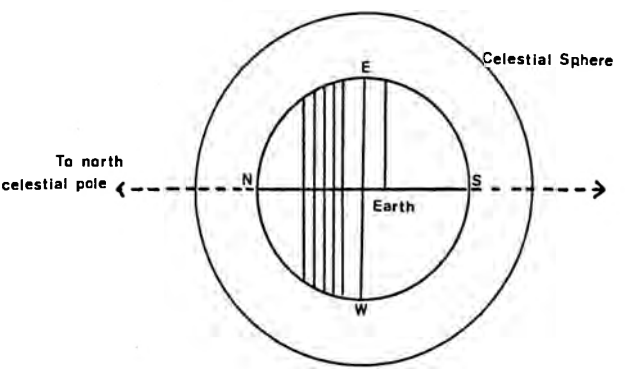


Fig. 2:1.

(note: it so happens that an observer in the northern hemisphere can "see" the north celestial pole (N.O.P.) as the star, Polaris, is located there.)

34 2. The Celestial Meridian. (see p.)

This is the arc passing through the poles and the observer's zenith which corresponds to the projection

of the observer's line of longitude onto the celestial sphere.

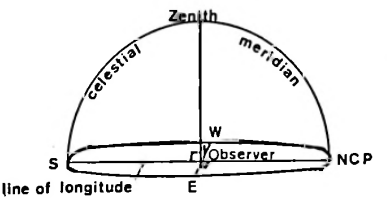


Fig. 2:2.

The Noon Meridian

This is the reference point from which we measure celestial longitude. However, we have to take two factors into consideration.

32 1. As bar Hiyya mentions (p.32), the celestial sphere appears to make a complete revolution around the earth in one day. Specifically, a star overhead will move westward by $\frac{360°}{24} = 15°$ in 1 hour. The upshot of the matter is that the heavens along the meridian are constantly changing. Since this situation would also apply to an observer situated at the terrestrial meridian, bar Hiyya picks a specific time viz: noon, in order to specify a particular part of the heavens.

2. This still leaves us with a problem which bar Hiyya at this point chose to overlook. This is the fact that not only do the stars at the meridian change from hour to hour, but at the same hour the next night, it will be observed

that the stars that lay along the meridian the previous night have inclined west by about 1°. (This is due to the revolution of the earth around the sun.) They keep inclining westward night by night until they once again attain the meridian a year later. Thus in order to assign a specific part of the sky to be used as a reference point, one has to specify the day of the year as well as the time of day.

It seems plausible that bar Hiyya determined the noon meridian as the celestial meridian for an observer located at the terrestrial meridian (the line of breadth,) at noon, on the day of the spring (vernal) equinox, the reason being that the sun would lie at the celestial equator (see section 3) which is our line of reference for celestial longitude. Thus the origin of the coordinate system would be well defined.

In this way the noon meridian would be "fixed" in the sky. Moreover, we can see from the constellation Aries, where the meridian passes.

Determination of the Noon Meridian at the Terrestrial Meridian on day of Spring (Vernal Equinox at 12:00 noon.

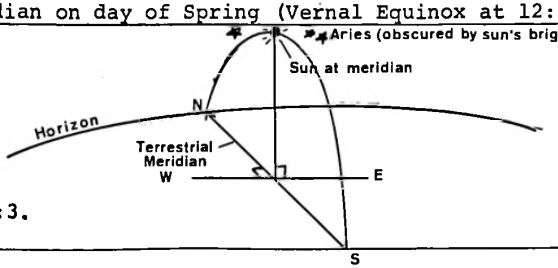
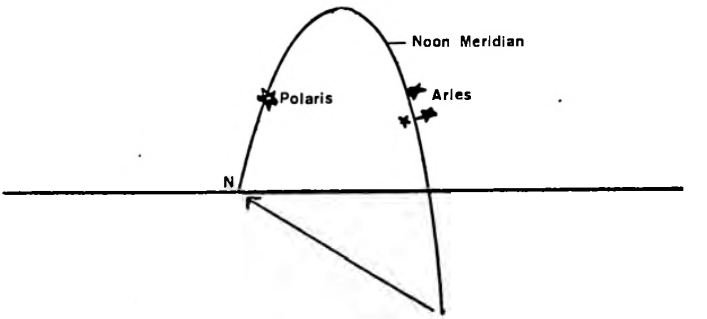


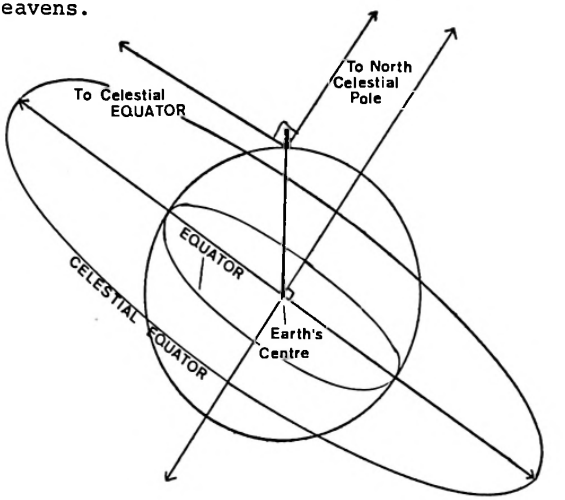
Fig. 2:3.

Determination of the Noon Meridian at night when Aries is visible.



3. The Celestial Equator.

This is the projection of the earth's equator onto the heavens.



As bar Hiyya mentions (p. 34) half of the celestial equator (180°) is always visible to an observer on earth. (Note: at the north or south poles the horizon and celestial equator coincide, see number 6).

Just as we use latitude and longitude to determine any position on the earth, we use declination and right ascension to determine the position of a star in the heavens. Declination is arc angle along the celestial meridian north or south of the equator.

The right ascension, which corresponds to longitude, is measured along the celestial equator in degrees, or hour angles. The "noon meridian" - or vernal equinox is 0° or 0 hours. Since the celestial sphere appears to move from east to west by 15° each hour, and hence appears to ascend towards the right to an observer facing south, the degrees or hours are measured off along the celestial equator to the left of the vernal equinox up to 360° or 24 hours.

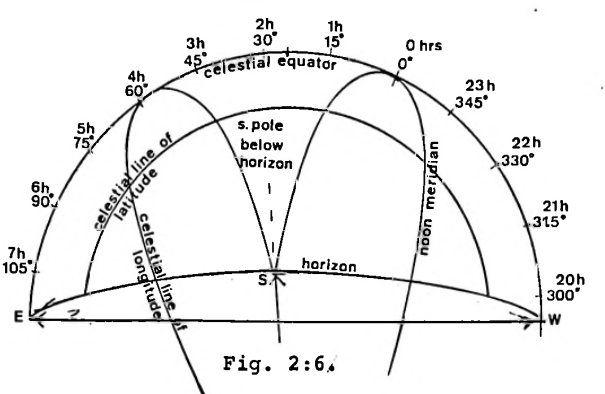


Fig. 2:6.

Some consequences:

i. Suppose a star A, has a right ascension of 13 hours. Then, if we know the position of the noon meridian in the sky, the star will be along that arc 13 hours later.

ii. Suppose we cannot see the noon meridian, but we know that the hour angle of a visible star B, is 6 hours 30 minutes and 25 seconds, then (13hrs. - 6h.29m.35s.=) 6 hrs. 30min. 35 sec. later, star A will be visible along that arc where star B was.

iii. (see p. 34.) At the spring and autumnal equinox, the sun appears to lie on the celestial equator. Since we already know that at all points on the earth (except the north and south poles), half (180° or 12 hours) of the celestial equator is visible, the sun will be visible for 180° or 12 hours. Consequently, day and night are exactly 12 hours each.

4. The Sphere of the Zodiac.

is the circle along which lie the twelve constellations: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces. Since there are 360° in one complete revolution, each constellation of the zodiac takes up exactly 30° along the celestial equator (see fig.2:7a). The reason why the shape of the zodiac is a sine wave is that the ecliptic (see next heading) is tilted at an angle of 24° to the equator, and the resulting shape from our vantage point on earth appears as

an ellipse (or the closed version of the sine wave below).

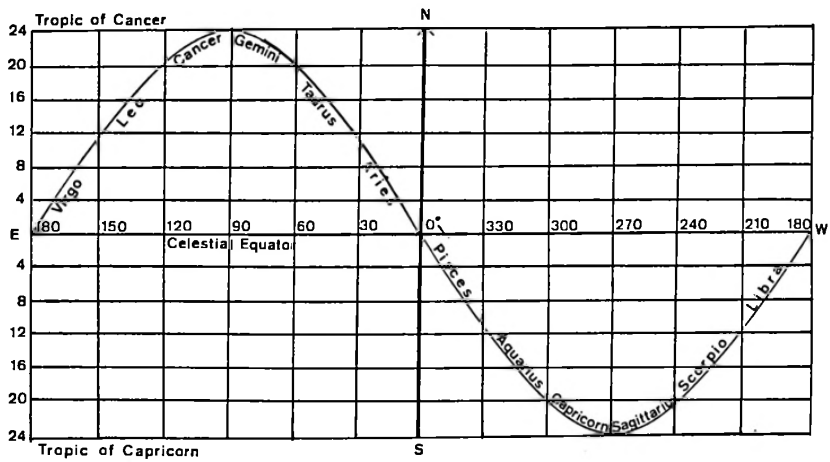


Fig. 2:7a.

5. The Ecliptic.

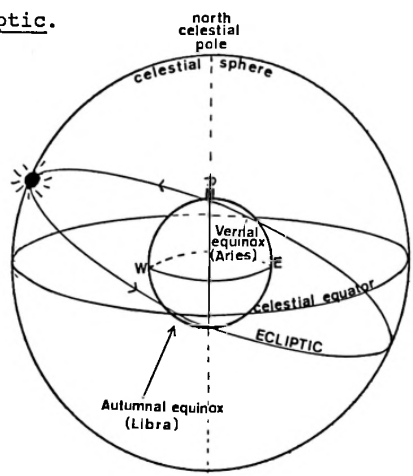


Fig. 2:7b.

The ecliptic is the path of the apparent eastward daily progress of the sun as seen against the fixed stars. As the figure shows, (and bar Hiyya mentions, p. 35) the sun also journeys north and south of the celestial equator during the course of the year, i.e. from the spring equinox, the sun would rise each day further north of due east, along the eastern horizon until the day after the summer solstice, when it would start to rise a little further south following the reverse path of the one it took the previous three months, until three months later, on the day of the autumnal equinox it would rise due east. For the next six months it would follow a similar progression southward of the celestial equator. (See commentary on gate three.)

The ancients were aware that the sun's brightness obscured the stars during the day - sometimes the brighter ones would be visible during a solar eclipse. They also knew the various constellations that were visible on the celestial sphere. Specifically, they noticed that the sun seemed to pass in front of 12 constellations which they then called the zodiac, in the order mentioned above. How could they tell what constellation the sun was in if the stars were obscured by the sun's brightness?

We already mentioned the apparant westward progress of the stars day by day (p.23 f.), in other words, new stars would appear before sunrise on the eastern horizon. The diagram illustrates the situation, and the solution.

Dawn December 1st.

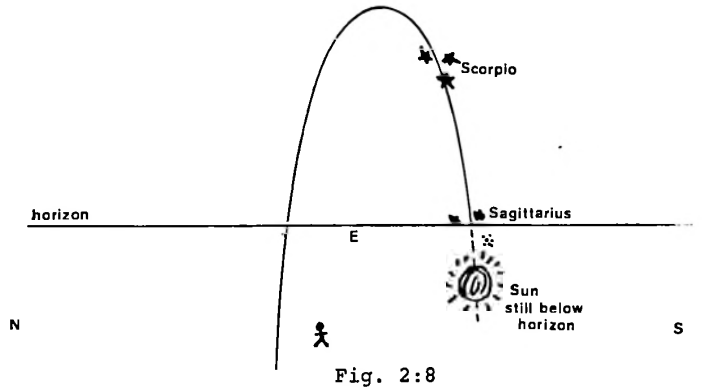


Fig. 2:8

Observer knows the stars which follow Scorpio, viz. the stars that make up the constellation Sagittarius. He also knows where Sagittarius is in the sky relative to Scorpio. He notices that the sun comes up where Sagittarius would be, thus he knows that the sun is "in Sagittarius".

A more direct way is to notice what constellation of the zodiac lies at the meridian at exactly 12 midnight, then the sun, which at this moment is at the observer's nadir, is in the constellation which is exactly 180° from the one directly overhead. For example, suppose the constellation directly overhead is 12° of Libra, this would be 192° along the celestial equator from the vernal equinox. Thus the sun is 192° - 180° = 12° away from the vernal equinox, ie 12° in Aries.

6. The Celestial Horizon.

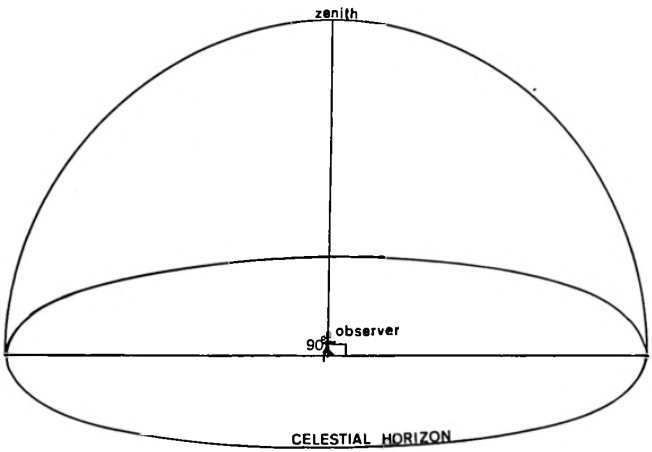


Fig. 2:9.

The celestial horizon is the circle which lies at right angles to the line from the centre of the earth to the observer's zenith. It need not correspond to the apparent horizon, which may be affected by the position of the observer. For example, if he is on the top of a mountain, the apparent horizon could dip below the celestial horizon.

THE SECOND GATE.

Concerning the shape of the heavens and the movement of the celestial sphere around the earth, and how the constellations of the zodiac in the the heavens turn north and south.

The sages of Israel, of blessed memory, like the sages of the nations, agreed as to the shape and structure of the heavens, viz: that it is spherical. It encompasses the whole earth above and below, east and west, north and south. It rotates around the earth from east to west, surrounding it. In one complete day it starts in the east and rotates around the whole earth both above and below[1] until it returns to the east where it started its rotation.

The heavens have two points as axes of rotation: one at the northern tip which is called in Arabic, the north kotebh (pole), and the other at the southern tip called the south pole. You could call them the hinges or pins of the heavens, except that the connotation of "hinge" would imply that it goes from one end to the other.[2] The poles, however,

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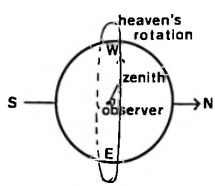
1. We tend to picture the earth with north pole "above" and south pole "below", for bar Hiyya, these lay horizontally while the heavens rotated "above and below".



2. i.e. that it moved in a swinging motion from east to west.

are like the two points which are at the two ends of the hinge, and these two points are permanently fixed and do not move. The earth is inside the heavens like a point inside a circle.

One sage compared this matter to if a man were to place a mustard seed inside an ostrich egg, or an egg-shaped glass, and set this between two nails and rotate the egg between these two nails at great speed. One would then see the mustard seed remain in the centre of the glass not turning towards any side. This, provided he spins the glass with much force, for the force of the movement of the glass does not allow the seed to turn left or right. You will find in this experiment that the nails which hold the glass do not move from their place.

Similarly, the heavens rotate on these two points which are called poles, and they remain fixed and do not move, while the heavens are supported by them in their movement.[3] It revolves around the earth from east to west at an enormous speed continually, while the earth remains in the middle of the heavens.

The force of the speed impels the earth on every side until it sets it in the middle of the heavens so that it

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3. הלוכתן, "their movement". In the light of the discussion, bar Hiyya would seem to be referring here to the heavens (sing. in Hebrew), and not the hinges as suggested by the text, SI p.9.

does not turn to any side, but its distance from the east is the same as the distance from the west, and its distance from the north is the same as its distance from the south.

Thus the distance of the sky which is over it above, is the same as the distance of the sky which is under it, below. It is in the heavens like a mustard seed in a large egg or glass. The reason why the sage chose such a small size was that the earth's size is so small when compared to the immensity of the heavens above, which surround it.

Its two poles are opposite one another. The one is in the furthest tip of the north and the other in the furthest tip of the south. The sphere which is above these two points is supported at north and south for its rotation. This is what accounts for and explains its characteristics.

The arc from this sphere over the earth is called the noon meridian. This corresponds to the earth's meridian in the figure I drew above.

There is another sphere intersecting this one, described at its halfway point and is at an angle of 90° from both north and south poles. The movement of the heavens is measured on this sphere. It is called the celestial equator and corresponds to the earth's equator, called the line of length in the figure I drew up before.

This sphere is divided into two equal parts. In all places in the world, half is visible over the earth and half is obscured under the earth. Because of this we find day

and night equal in all places of the earth when the sun is on this sphere, viz. the time when it is at the entry of Aries or the entry of Libra.

The sphere of the zodiac, which we see as corresponding to the sun's motion, intersects these two points. There are twelve constellations on this sphere. Each constellation is divided into 30°, so the whole sphere is divided into 360°.

The sun revolves in the heavens in correspondence with the sphere of the zodiac. The latter is inclined from the celestial equator north and south at an angle of 24°, and divides the celestial equator into two equal parts at the two mentioned points. These are called equinocial points, (lit. points of equity), since at these stages, day and night are equal in every location.

The first at the entry of Aries: day and night are of equal length in every location when the sun is at the entry of Aries. From here on the daytime exceeds the nighttime in the northern hemisphere.

The second, at the entry of Libra: similarly day and night are of equal length, except that from here on, the nighttime exceeds the daytime.

Conversely, you find that the celestial equator bisects the sphere of the zodiac. Half of it is north of the celestial equator by an angle of about 24°. The six northern constellations are in this hemisphere, viz. Aries, Taurus, Gemini, Cancer, Leo and Virgo. The other half of

it is south of the celestial equator by an angle of about 24°. In this hemisphere are the so-called southern constellations, viz: Libra, Scorpio, Sagittarius, Capricorn, Aquarius and Pisces.

The two points on the zodiac which are of the greatest distance from the celestial equator are called the solsticial points, (lit. points of permutation). The one is at the entry of Cancer - at which point the day reaches its maximum duration and from there on diminishes while the night increases, the other is at the entry of Capricorn, at which point the night reaches its maximum duration and from there on diminshes while the day lengthens.

The heavens are always divided everywhere into two equal parts. One half is visible above the earth, while the other half is obscure beneath the earth. The circle which divides off the visible half from the non-visible half of the heavens everywhere, is called the celestial horizon of that particular place.

Any circle which rotates or revolves in the heavens, we call a sphere.[4] Any circle which we single out because of its revolution or rotation, we designate as a meridian.[5]

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4. i.e. celestial lines of latitude, see fig.2:6. p.26.

5. i.e. celestial lines of longitude.

COMMENTARY TO THE THIRD GATE.

As the sub-heading indicates, the subject of this gate is the way the movement of the celestial sphere alters as one moves in a north - south direction.

One feature that becomes clear as we progress through the chapter, is that the position of the celestial equator, or rather its declination from the zenith, and the position of the celestial poles in the sky, are dependent on the observer's latitude. For example, at latitude 31° north, the equator declines 31° south of zenith, while the north celestial pole is inclined at an angle of 31° above the northern horizon. Figure 3:0 illustrates the general case.

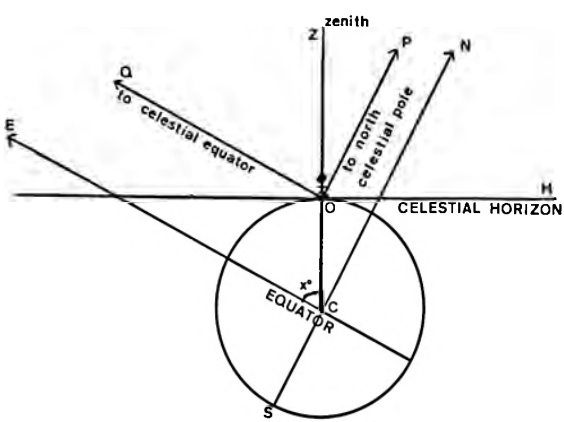

Fig. 3:0.

Proof.

As we mentioned previously, the directions from the earth's centre to the north celestial pole and the celestial

equator, are parallel to the directions from the observer at O to the the north celestial pole and celestial equator respectively: i.e. OP // CN and OQ // CE.

Given that the observer is at x° north ($0° \leq x \leq 90°$)

The declination of the equator from the zenith along the observer's meridian (for definition see p. 22.) is x° (corresponding angles of parallel lines). We know that the angle between the equator and poles is 90°,

therefore: $OCN = 90° - x = ZOP$ (corr. angles)

but $ZOH = 90°$ by definition of zenith,

therefore $POH = 90° - (90° - x°) = x°$.

In other words, the inclination of the north celestial pole above the northern horizon is x°. Q.E.D.

Since the sky appears to rotate on the poles (p. 32f.), that rotation will change according to the latitude of the observer. bar Hiyya describes the features of the rotation of the skies at nine different latitudes. We will illustrate how the sky rotates at some of these latitudes so as to give the reader an idea of what bar Hiyya is describing.

The sky at the equator. (text, p.49.)

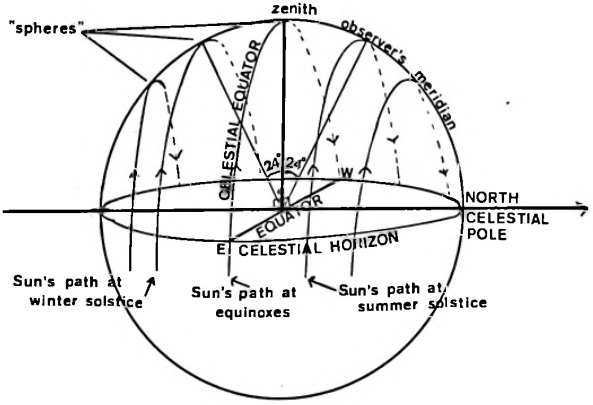

Fig. 3:1.

As you can see, the celestial lines of latitude (called "spheres") are all bisected by the celestial horizon. We shall see why bar Hiyya refers to "obscured poles" when we deal with other latitudes.

With regard to the day's length, recall that the sun, in moving along the ecliptic, appears at the celestial equator on the days of the equinoxes and otherwise is inclined either north or south of it up to an angle of about 24°, (cf. p.35f.).

Take the case when it is inclined 24° south of the celestial equator (on the day of the winter solstice for the inhabitants of the northern hemisphere; summer solstice for the inhabitants of the southern hemisphere; when the

sun is at the entry of Capricorn; December 22nd or the t'kuphah of Tebheth). The sun will take 24 hours to move around that imaginary circle in the sky. Half the circle is occulted from the observer, therefore half the time, the sun will be obscured from the observer, viz. for 12 hours. It will be visible for the 12 hours remaining. The same is the case for any position the sun has along the ecliptic, since all the celestial lines of latitude are bisected by the observer's celestial horizon. Note, this latter feature is only the case for observers at the earth's equator.

Observer at 16° north. (p. 50.)

Once again, the figures illustrate the situation.

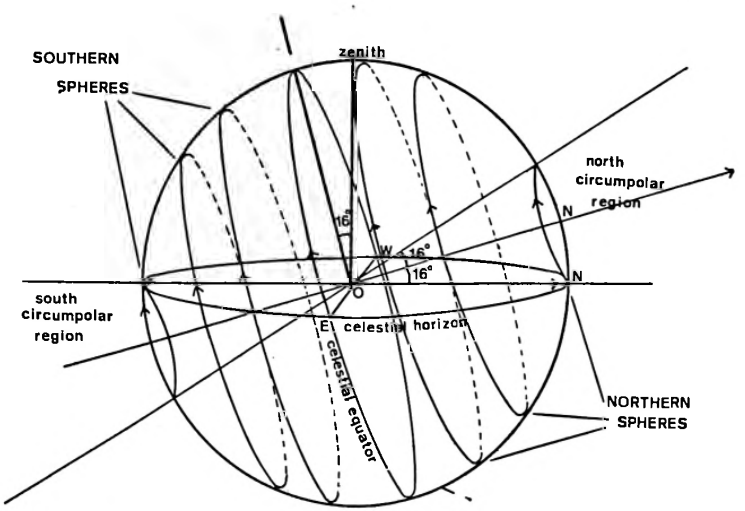

Fig. 3:2.

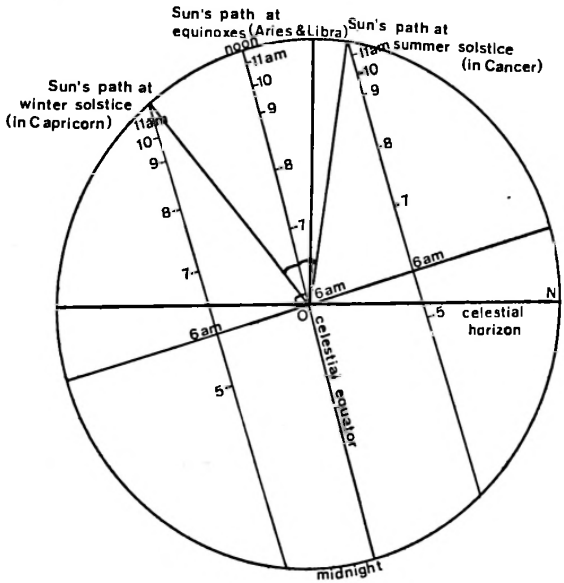

Fig. 3:3.

End elevation - to mark off hours of the day.

Note:

1. (Fig. 3:2) The north circumpolar region (16° around the north celestial pole). In this area, the stars are visible throughout the year. Correspondingly, the stars of the south circumpolar region are occulted throughout the year.

2. (Figs. 3:2 & 3) The arcs of celestial latitude are inclined at an angle parallel to the celestial equator. The diagrams show how the celestial horizon only bisects the celestial equator. In the case of the other spheres, the northern ones have a greater portion visible than

obscured at any one time, while the southern ones have more obscured at any one time than visible.

3. (Fig. 3:3) The effect on the amount of daylight during the year is thus effected - as bar Hiyya points out. (p. 51) When the sun is inclined south of the celestial equator the days will perforce be shorter, because the greater part of the circles on which the sun revolves in 24 hours is obscured below the horizon. Conversely, when the sun is inclined north of the celestial equator the days will be longer, since the greater part of the circles of latitude are visible and consequently the sun is visible for the greater period of time.

Observer at 31° north (p.52)

Basically the same considerations apply here as to an observer at 16°.

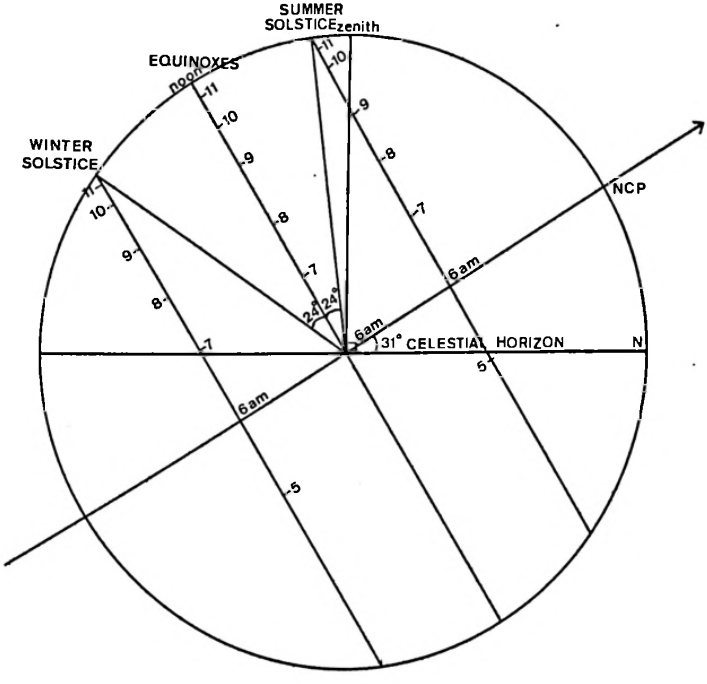

Fig. 3:4

Fig. 3:4. Schematic diagram to show how the latitude affects the day's length. (End Elevation)

This diagram shows how the angle at which the celestial equator declines from the zenith influences the number of hours the sun is visible. As you can see, during the winter solstice the dawn breaks at about 6:56 a.m. and sets at 5:04 p.m. making for a day of length 10 hrs and 8 minutes. Correspondingly, the sun rises at 5:04 a.m. (i.e. 56 minutes earlier) at the summer solstice and sets 56 minutes later at 6:56 p.m. making for a day of length 13 hrs. 52 minutes.

A similar situation occurs at 41° north (described on page 53) and 49° (see page 53 also). The amount of the declination of the celestial equator becomes greater and the difference in length of days and nights correspondingly becomes greater.

66° north - The Arctic Circle. (refer to p.54)

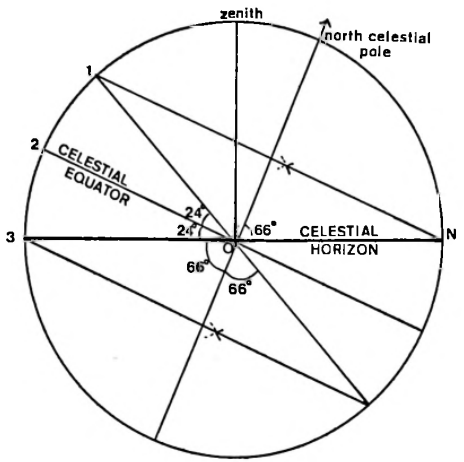

Fig. 3:5.

Fig. 3:5 (End Elevation)

The figure represents the situation as if we were looking at the observer from a point on the same horizontal plane due east of him, (like the two figures previous). Thus the sun's path looks to us like a straight line. The main difference here is that on the day of the summer solstice, the sun takes 24 hours to complete its circle before dipping below the horizon.

1. On the day of the summer solstice, the sun starts its ascent midnight due north, and moves in a circle towards the east until it reaches its maximum height (48°) due south. It finally sets due north again 24 hours after its dawning.
2. On the days of the equinoxes, it rises 6 a.m. due east and sets due west 12 hours later. It reaches a maximum height of 24° (23 1/2° to be exact) at noon.
3. On the day of the winter solstice, the sun does not rise for 24 hours. The brightest time of day is 12 noon, when the sun is just below the horizon due south.

Observer at 69° and 78°

These latitudes follow basically the pattern outlined for the arctic circle (66°) except that, as bar Hiyya mentions (p. 55) the 24 hour day lasts correspondingly longer, the farther one progresses north.

Observer at 90° (or at the north pole.)

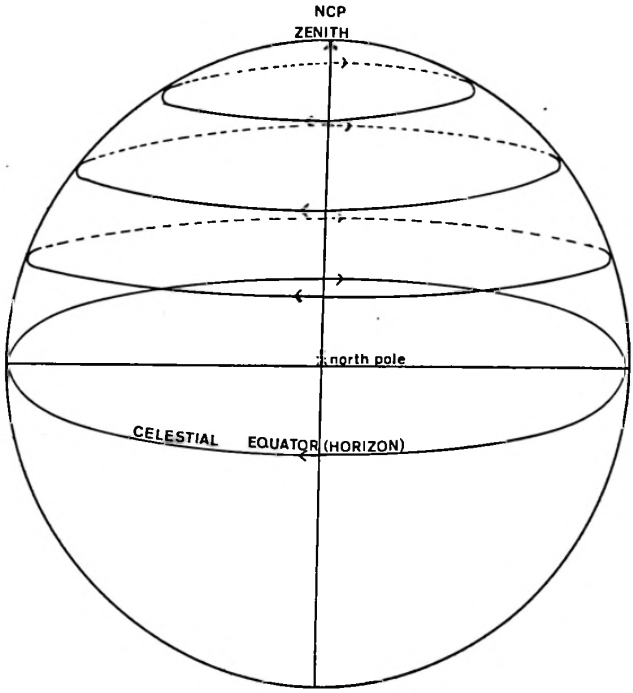

Fig. 3:6

Here the north celestial pole is directly overhead (see p. 56) and the lines of celestial latitude run parallel to the horizon which itself merges with the celestial equator. Thus the stars appear to move parallel to the horizon. It takes 6 months - from vernal equinox to autumnal equinox for the sun to rise and set, i.e.

as long as the sun is in the northern constellations or above the celestial equator. From the autumnal equinox to the vernal equinox (i.e. during the winter months), the sun is always occulted, and we have the 6 month night.

With regard to bar Hiyya's discussion on the southern hemisphere, he basically means to say that the situation is the converse, as one travels South, to the one as one travels north. eg. at 31° south, the celestial equator is inclined north by 31° from the zenith etc. Note, however, that at 31° south the longest day is the shortest day at 31° north. By simply exchanging north for south and vice versa in the diagrams and explanations, you can see why this is so. Note too, that during the north's winter months, the south is experiencing its summer, because at this time the sun is among the southern constellations and therefore more directly overhead the people south of the equator while for the people in the north it reaches its greatest obliquity from the zenith.

The last section of this gate deals with the exegesis of the Job verse. Here, bar Hiyya tries to show how even in Biblical times, it was known that there was a 6 month summer day at the north pole, and that this corresponded to the 6 month winter at the south pole and vice versa. He draws his exegesis from the Bible's reference to "breadth" rather than"length" and hopes in this way to build his case.

Hence he would have us conclude, the early Hebrews did not have to pick up their knowledge of astronomy from the Greeks or Babylonians.

THE THIRD GATE

Concerning the differences which can be found in the ecumene from the north to south.

Anyone who lives at the equator [1] will have the celestial equator revolving directly overhead from east to west. The two poles are seen one due north, the other due south. Consequently the southern constellations are south of zenith and the northern ones north of zenith. [2] For them the sphere which divides off the visible from the non-visible part of the heavens [3] passes through the two polar points and divides up all the meridians and spheres of the heavens into two equal parts.[4] One half is visible while the other occulted. On account of this, day and night are always the same length for them throughout the year. The revolution of the heavens in such a place is well ordered and normal. Not one of the poles is ever obscured from them, neither does one ascend or descend.

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1. see fig. 3:1 (p. 39)

2. bar Hiyya is referring to the signs of the Zodiac. viz: Aries through Virgo are the so-called northern constellations, while Libra through Pisces are the southern ones. (cf. figs. 2:7a and b p. 28)

3. i.e. the celestial horizon.

4. Refer to commentary on this section

Those who live at the latitude of the first climate are a distance of 16° [5] from the equator. They are inclined north and consequently the celestial equator does not lie directly overhead as it does for those who live on the equator. Instead it is inclined from the zenith at an angle of 16° south. The celestial horizon does not pass through the polar points but is inclined from each one at an angle of 16° The south pole [6] is always occulted and consequently all those stars which are within its domain and inclined to it up to an angle of 16° are always obscured from them. However, the north pole is above them and is never obscured, but is always visible to them. All the stars which are inclined to it up to an angle of 16° are never occulted and never sink below the horizon. The celestial horizon does not bisect the spheres and meridians[7] into equal parts, with the exception of the celestial equator. It divides those spheres which are inclined north

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5. see fig. 3:2 (p. 40)

6. When bar Hiyya refers here to south pole, he of course means the south celestial pole. Context should determine whether pole is celestial or terrestrial.

7. see diagram and explanation on this in the commentary (p. 40)

of the celestial equator into unequal parts[8] so that the part which is visible above the earth exceeds that which is obscured. Conversely, with those spheres which are south of the celestial equator, a greater part of them is obscured beneath the earth than can be seen above it. Consequently the day's length exceeds that of the night whenever the sun is among the northern constellations; from the entry of Aries to the end of Virgo, while the nights are longer than the days whenever the sun is among the southern constellations which are from the entry of Libra to the end of Pisces.

When the sun is actually at the entry of Aries or the entry of Libra, the lengths of the day and the night are equal because at that point it moves along the celestial equator which is divided into two equal parts in all locations, as we have explained previously.[9] The amount of

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8. celestial lines of latitude -- see figs. 3:2 and 3:3.

9. cf. P.34f.

increment in this place by which the longest day exceeds the equinox does not exceed one hour.[10]

Those places where the day exceeds the night or is diminished from it by two hours are located at a distance of 31° from the equator. The celestial equator is inclined from the zenith 31° south while the north celestial pole and all the stars which lie within its domain up to an angle of 31° are always above the celestial horizon and throughout the year are visible and never obscured from those who live at this latitude. The south celestial pole and all the stars in its domain up to an angle of 31° are perpetually obscured. The northern spheres are divided by the celestial horizon into unequal parts, but that which is visible exceeds that which is obscured and the excess at the entry of Cancer is about two hours.[11] Consequently, their longest day is 14 hours and the corresponding night 10 hours. The spheres of the southern constellations are divided contrariwise: the obscured part exceeding that which is visible until it reaches about 2 hours at the entry of Capricorn, when the shortest day is

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10. i.e. the northern sphere outlining the sun's path on the day of the summer solstice has a little less than 15° of arc (1 hr. = 15°, $\frac{360}{24}$) over 180° visible at any one time.

11. cf. previous note. Here about 210° (180° + 30°) of arc are visible at any one time.

10 hours and its corresponding night 14 hours.

For those who live on the latitude which is 41° from the equator, the celestial equator is inclined south of the zenith by 41°. The north celestial pole with its stars lies above the horizon and they are always visible within an angle of 41° of it. As for the spheres of the northern constellations, those parts that are visible exceed those parts which are obscured up to 3 hours. The longest day is 15 hours and its corresponding night 9 hours. That which is obscured of the southern spheres exceeds that which is visible to a corresponding extent so that the shortest day is 9 hours and its matching night 15 hours.

For those who live at a latitude of 49° away from the equator, the celestial equator is inclined south at an angle of 49°. Correspondingly, the north celestial pole lies higher overhead and is never obscured, thus the south pole is obscured and cannot be seen. The parts of the northern spheres which are visible exceed those obscured up to 4 hours; contrariwise, in the case of the spheres of the southern constellations. Consequently, the longest day is 16 hours, and the shortest day 8 hours.

In a similar manner, as one goes further north, increasing one's distance from the equator, one finds that the celestial equator inclines increasingly south of the zenith while the north celestial pole ascends higher and (a greater domain) becomes increasingly visible, while the south

celestial pole descends and is occulted. Likewise, the length of the longest day increases while the length of the shortest day decreases until one reaches the location which is a distance of 66° from the equator.[12]

One finds in this place that the celestial equator is inclined south at an angle of 66°. The south celestial pole is obscured under the earth by an angle of 66° and consequently the entry of Capricorn is always obscured from these people, for the entry of Capricorn is exactly at an angle of 66° from the south celestial pole. You can understand this upon a little reflection, because you know that the angle between the celestial equator and each of the two poles is 90°, and the angle between the entry of Capricorn and the celestial equator is 24° south.[13] Subtract this from 90° (which is the angle to the celestial equator), and the remainder 66° is the angle to the entry of Capricorn. All these degrees [14] are obscured below the horizon in these parts, and the entry of the sign of Capricorn is obscured with them.

Thus the north celestial pole and all the meridians and spheres and stars which adjoin it within 66° are always visible in this place. The entry of the sign Cancer is

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12. This is the arctic circle. See fig. 3:5, p.44.

13. see p.35f.

14. see fig. 3:5 p.44.

visible among them. It is never obscured since it is the same angle from the north celestial pole as the angle of Capricorn from the south celestial pole.[15] While the entry of Capricorn is occulted, the entry of Cancer is visible, and when the sun is in the entry of Cancer, it can be seen the whole day revolving around the earth and not dipping below the horizon, by those who reside in that location. When it is in the entry of Capricorn, it is obscured from them the whole day and cannot be seen. The longest day is 24 hours of uninterrupted daylight, while the "shortest day" is night for 24 hours with no daylight at all.

The populated domain extends up to this point in the northern hemisphere and from hereon there is no settlement. But reason dictates - while investigation and logic testify - that in a location which is a distance of 69° from the equator, the north celestial pole has an angle of 69° to the horizon, and the two constellations Gemini and Cancer,[16] are always above the horizon and are never obscured. Consequently, when the sun is in Gemini and Cancer, it rises over this location and remains above the earth and is not obscured for the entire duration of these two months.[17] When it is in the two corresponding constellations, viz.

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15. i.e. 66°

16. cf. figs. 2:7 a and b, p.28.

17. i.e. while the sun is in these two constellations.

Sagittarius and Capricorn, it is obscured beneath the horizon and cannot be seen. In this location, there are two months of daylight and correspondingly two months of night. During the remaining months of the year, days and nights combined are 24 hours; the day either exceeding the night, or the night exceeding the day. At the time when the sun reaches the entry of Aries or the entry of Libra, day and night are equal in the manner of the other locations in the world.

In the location which is at an angle of 78° from the equator, there are four constellations which can always be seen, viz. Taurus, Gemini, Cancer and Leo, and there are four months of daylight since the sun does not set below the horizon. Consequently, there are correspondingly four constellations, viz. Scorpio, Sagittarius, Capricorn and Aquarius which are always obscured. These four months are night, because the sun does not appear above the horizon. In the remaining months of the year, each day with its corresponding night consists of 24 hours.

At the location which is at an angle of 90° from the equator, the north celestial pole is at the zenith, while the celestial equator becomes the celestial horizon, (demarcating) that which can be seen of the heavens, from that which is obscured. The six northern constellations, from the beginning of Aries to the end of Virgo, are always

ascendent,[18] while the six southern constellations, viz. from the beginning of Libra to the end of Pisces, are always obscured. In this location, the rotation of the heavens differs and does not rise and set over the observer. Rather, its rotation resembles the rotation of a pair of millstones.[19]

Consequently, the sun can be seen for six months above the horizon throughout the time it is among the southern constellations. The year is divided completely into two equal parts, the one, day, the other, night.

The above describes the rotation of the heavens, the divergences in the sun's position over the earth and the lengths of days and nights in the whole of the northern hemisphere.

It is unnecessary for me to explain the details of the southern hemisphere, since you can understand them by inverting the details concerning the northern hemisphere.[20] At any location in the north which we mentioned, whose distance from the equator is x, and to which we assigned a certain length to its days and nights, the distance corresponding to it in the south will have days and nights

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18. i.e. above the horizon.

19. i.e. the heavens rotate in a circle parallel to the horizon.

20. see astronomical commentary p.46.

of opposite length to those of the northern hemisphere.[21] Likewise, up to the location where the year is divided into two equal parts, you will find that the six months which are day in the north, are night in the south, and the night in the north is the day in the south.

I saw that those sages who were punctilious in the explanation of the scriptures, discovered a veiled hint [22] concerning the duration of light in one place for many days from this verse:

> "Where is the way to the dwelling of light,
> And as for darkness, where is the place thereof..." [23]

"Where is the dwelling of light," i.e. in what place does light remain for six months?

"And as for darkness, where is the place thereof..." i.e. in these six months during which the light stays in this place, where is the place where darkness remains?

The proof of this matter comes from the verse which precedes it, which is,

> "Hast thou surveyed unto the breadths of the earth?
> Declare if thou knowest it all." [24]

The Holy One, Blessed be He, said to Job, "If you were to go through the settlements of the earth from north to south

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21. cf. p. 16f.

22. see commentary p.47.

23. Job 38:19.

24. ibid. v. 18.

and survey the breadths of the earth, and you felt you knew its breadth, please tell me in which location does the light remain for three, four and six months without turning away? And at the time when the light is here, where is the place where it is dark? 'Declare, if thou knowest it all!'" It states "Hast thou surveyed unto the breadths of the earth" and did not say the "lengths of the earth," because the length is from east to west and light, in this regard, does not undergo such a change, but the breadth of the earth stretches from north to south and there the light and darkness remain for many days as we mentioned above.

We have just discussed the matter of locations which are on the breadth of the earth and the differences between them from the furthest reaches of the north to the furthest reaches of the south. We now come to explain, with God's help, the differences between locations which extend over the length of the earth, from east to west.

COMMENTARY TO THE FOURTH GATE.

The basic discusiion is the difference in time one encounters as one travels from east to west (or vice versa), viz. in the course of 15° of arc traveled west, one "loses" an hour. Figure 4:1 illustrates the situation. For the sake of simplicity, we are looking at the equator "end on", i.e. from somewhere in line with the south pole. In this way, we can see how the curvature of the earth plays a part in the visibility of the sun. Remember that every day on the equator begins at 6 a.m. (cf. p.49.), i.e. the sun is just at the horizon as of this time, not fully visible.

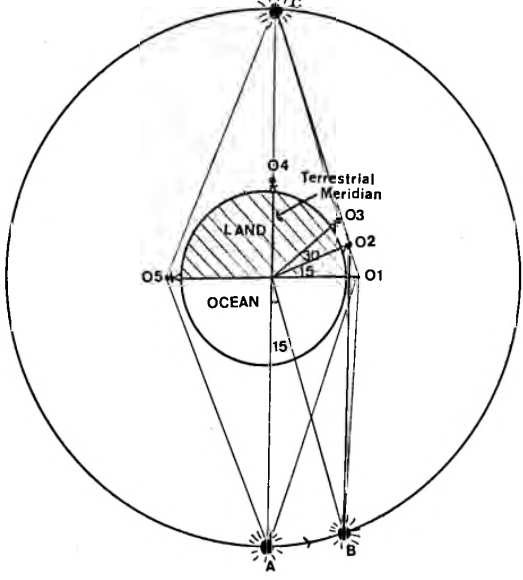

Fig. 4:1.

Sun at A.

6 a.m. at O1, 5 a.m. at O2, 4 a.m. at O3, midnight at O4, 6 p.m. at O5.

Sun at B.

7 a.m. at O1, 6 a.m. at O2, 5 a.m. at O3, 1 a.m. at O4, 7 p.m. at O5.

Sun at C.

6 p.m. at O1, 5 p.m. at O2, 4 p.m. at O3, noon at O4, 6 a.m. at O5.

Remember, that a change in time is continuous as one changes longitude. For example, if A is only $7\frac{1}{2}°$ west of B, the time at A is half an hour earlier than that at B; if it is 15' west of B, then the time at A will be 1 minute earlier than that at B. Similarly, if A is 15° west of B, the time at A will be 1 second earlier than that at B.

THE FOURTH GATE.

Concerning the diversity which is apparent in the inhabited areas from east to west.

Know that the distance of east from west is 180°; half the number of degrees in the heavens,[1] since the heavens are completely divided up into 360°.[2] They are always divided into two equal parts; the one half, above the earth, is 180°, and the other half, below the earth, is 180°. Thus you can deduce that the distance from east to west on the opposite side of the earth is 180°.

If you divide each of these two halves into twelve sections corresponding to the number of hours in a day and a night, each section will be 15°. This is the measurement of one hour in our present context.

When the sun rises and shines in the furthest edge of the east, it is visible to all those who inhabit the beginning of the eastern edge of the earth and that time is the beginning of the day for them, but it is not visible to any of those who live further along the length of the earth, but this time is still night for them.

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1. i.e. the celestial sphere.

2. Practically speaking, the arc along the celestial equator subtends an angle of 360°.

When the sun rises from the eastern extremity until it is visible above the earth at the end of the eastern edge at an angle of 15°,[3] it appears to all locations which are 15° distant from the beginning of the eastern edge as just starting to shine on them. That time is daybreak for them.[4] The difference between daybreak in this location and its breaking at the eastern edge, is one hour.

As the sun continues to ascend and gain height over the earth at the eastern edge to an angle of 30°, it can be seen as just starting to shine on those who inhabit locations which are a distance of 30° from the eastern edge. Daybreak in this region is at the end of the second hour of the day at the eastern edge.

Similarly when it ascends to an angle of 45°, it shines on those locations which are a distance of 45° from the eastern edge. There is a difference of 3 hours between daybreak for them and its beginning at the eastern edge.

Likewise, those a distance of 60° from the eastern edge have a difference of 4 hours between their daybreak and its beginning at the eastern edge. Those at a distance of 75° have a difference of 5 hours while those at a distance of 90° - they inhabit the central region of the earth - have a difference of 6 hours between themselves and the eastern

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3. 15° i.e. one hour has elapsed.

4. i.e. 6 a.m.

edge. The beginning of the day for those who inhabit the central region of the earth is noon for those who inhabit the eastern edge.

In this manner it continues until it comes to the inhabitants of the western edge. The sun, itself, moves away from the eastern edge a full 180° (half the heavens), i.e. 12 hours. At this time the sun sets at the eastern edges and this is nightfall for them, while it shines above the people of the western edge and this is daybreak for them. Consequently daytime for the people of the east is night for the people of the west, while night for the former is daytime for the latter. This place is the end of the earth's settled area. There is nothing beyond it except the waters of the ocean which are impassable.

You can infer from this that day and night are never the same in all places around the earth, neither in length,[5] nor in time, but a day which has a known length in one place will be longer or shorter in a different place. Concerning this matter as to whether night is longer or shorter in different places except for two days in the year when day and night are equal in all settled locations, viz. when the sun is at the entry of Aries and the entry of Libra; you have already seen that they are not equal in length in every place; likewise they are not equal in their time, rather, at one hour of the day the sun is seen in one place

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5. See gate three on divergences as one changes latitude.

but is not seen in another: here it is day and in the latter, night. Except at two moments, you will not find the sun visible throughout the extent of the settled area at the same moment, nor, similarly, obscured from all the settled area at the same moment of the day.[6] The one moment occurs when it is at mid-point across the the heavens directly above the inhabitants of the central region of the earth. This is midday for them, and at this moment it rises over the people of the west and sets from the people of the east. It is at its zenith for those who live in the central regions of the earth. For those who live east of the central region, it appears to them as directed from the zenith westward. For those who live west of the central region of the earth, it appears to them east of their zenith, ascending to the mid-point of the heavens. At this moment, it is visible in all the settled areas.

The second moment, when it is obscured from all the settled areas, is the point when it is midway across the heavens which are below the earth, opposite the antipodes of those who inhabit the central region of the earth.

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6. bar Hiyya is drawing a parallel to the fact:that just as there are two equinocial days in a year - where day and night are equal in all places, there are two similar moments of the day, one, when the sun is visible in all parts of the ecumene, the second when the sun is not visible in any parts of the ecumene i.e. 12 noon and 12 midnight at the terrestrial meridian.

COMMENTARY TO THE FIFTH GATE.

bar Hiyya begins the explanation of the dimensions of the earth by showing that "length" and "breadth" are derived from the population distribution. He then tries to show, by means of scriptural exegesis, that here again, the Bible was aware of the distinction in the length and breadth of the populated area. This is consistent with his attempt to prove that the secular sciences are already to be found in the Bible.

He next points out that theoretically it is possible to measure the length of the earth using a measuring line, because the whole terrain is traversible. He also suggests that the distance around the other (uninhabited, ocean) side is no greater than the length of the populated area. This he already hinted at in the first gate (p. 15) when he said that the side of the earth which was ocean had the same dimensions as the side which was land. He also actually stated the number of degrees in the populated and ocean side in the previous gate (p. 62).

The breadth, or longitudinal distance, of the earth is not measurable, because the extremes in temperature as one progresses north or south become finally intolerable (cf. p. 17). Once again this factor is "accounted for" in scripture.

Next, bar Hiyya deals with the question of measuring the

the dimensions of a country in degrees of arc and/or hour angle.

Measurement of length (north-south) by means of the sun's declination.

(note that one basically uses the information given in the third gate.)

At the southernmost tip of a country we note that along the celestial meridian, the sun is inclined, say, 15° from the zenith. On the same day, a person at the northern boundary notices that along the celestial meridian, the sun is inclined 30° from the zenith, thus the country is 30° - 15° = 15° broad.

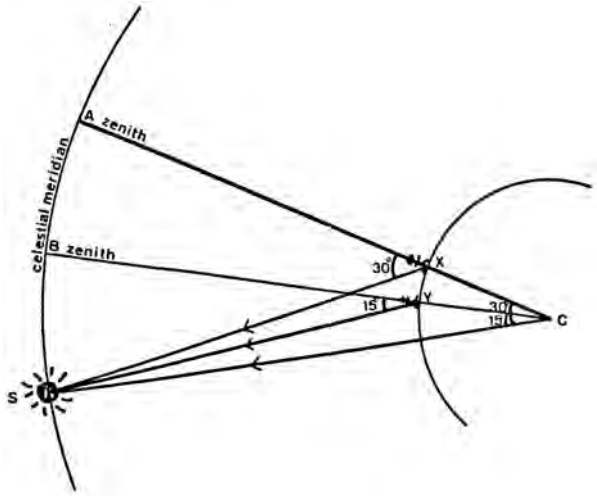

Fig. 5:1.

Since the distance to the sun is so great, XS // CS and YS // CS.

AXS = ACS = 30° and BYS = BCS = 15° (Corresponding ang.) Clearly XCY = ACS - BCS = AXS - BYS = 30° - 15°, and this gives us the angular distance between X and Y. In this way the declination of the sun helps us determine the breadth of the country.

Measurement of length (east-west) by means of a lunar eclipse.

(This uses some of the concepts discussed in the fourth gate)

One reason why this method is satisfactory in determining the "length" of a territory is that the lunar (unlike the solar) eclipse can be seen from any part of the hemisphere which is facing the moon.

First we have to have some consensus as to what time we are going to use. The astronomical day either began at noon of midnight (see gate 9) i.e. at the moment when the sun crossed the local celestial meridian, was directly opposite the earth directly below. (By knowing where the sun was along the ecliptic, one could figure out which stars crossed the celestial meridian. Also, every 15° along the celestial equator towards the east represented an hour's motion of the celestial sphere (cf. fig 2:6, p.26), thus if the stars opposite were 15° east of the celestial meridian, it would be 11 o'clock local time.) Thus each

position along the length of the earth would have its own local time.

Now since the eclipse occured at only one particular moment - but at many different local times, these different times could be compared. Since it was known that a difference of 15° longitude east meant a gain of one hour, while 15° west meant a loss of 1 hour. (see p.76) , the exact difference in time could be translated into an exact difference in longitude, as fig 5:2 illustrates.

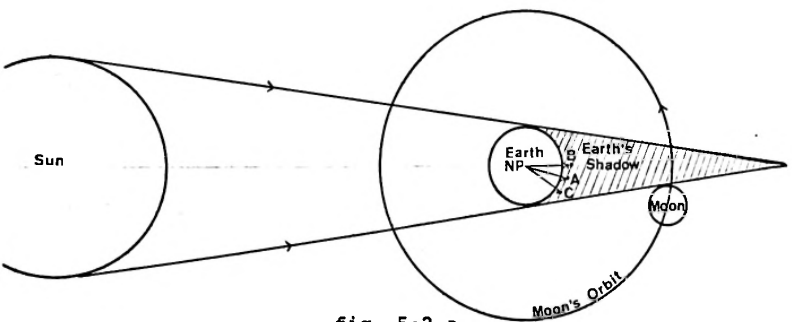

fig. 5:2.a.

The figure illustrates the position of the moon just about to enter the eclipse. As you can see the local times at A, B, and C respectively are 11 p.m., 12 midnight, and 10 p.m. This translates into a longitudinal distance of 15° between A and B, and A and C.

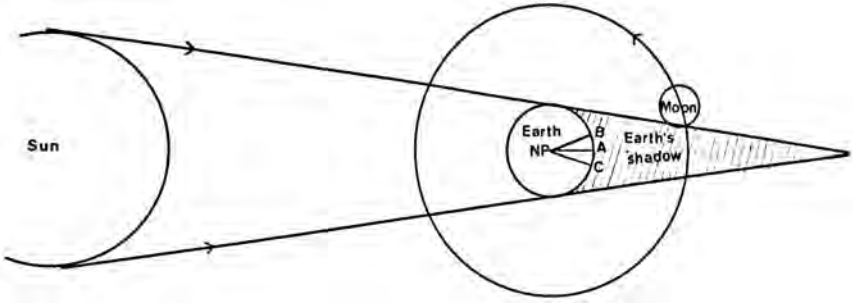

fig. 5:2.b

Here, the moon has just left the earth's shadow. In the meantime the earth has rotated 15° east (or the sun has apparently revolved 15° west). Now the times are A:12 midnight, B: 1 a.m., C: 11 p.m. Once again this translates into a longitudinal distance of 15°.

THE FIFTH GATE

Explaining the length and breadth of the earth and why one is called length and the other, breadth.

By now the characteristic behaviour of days and nights in the whole populated area and the changes in measurement which occur among them throughout the days of the year, over the breadth of the earth which is from north to south should be clear to you from the past gates, and similarly, the change which occurs from east to west should be clear to you.

The distance from north to south was called the breadth of the earth because the population in this direction does not stretch from one edge to the other. Instead, there remains a desolate wilderness: one at the northern extremity and the other at the southern extremity.

The distance from east to west was called the length of the earth because its population extends from one end to the other and the connotation of"length" in every language is an excess in its size over breadth. Because of this they called the distance which exceeded and was fully populated "length", while the distance which was narrow and deficient in population "breadth". Thus we find the verse:

"Up, walk about the land, through

its length and its breadth,
for I give it to you." [1]

"Length" of the earth, in this verse, was made to precede its "breadth", and He promised him that all would be given to him, when He explained to him the way it would be given, He said:

"...you shall spread out to
the west and to the east, to
the north and to the south."[2]

You find in this verse, that east and west precede, corresponding to "its length" which took precedence in the preceding verse. "North" and south follow, corresponding to "and its breadth" which followed above. You will discover from the Torah, that the length of the earth is from east to west, while its breadth is from north to south. Thus it is written:

"As far as east is from west
has He removed our transgressions
away from Him."[3]

and it did not say "as far as north is from south" because the distance of north from south in the populated

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1. Gen 13:17
2. Gen 28:14
3. Psalms 103:12

part of the earth does not extend from beginning to end, and if it had said as far as north is from south, people would have inferred that the Holy One, Blessed be He, does not remove the transgressions [4] of His people the complete distance possible, for there is a greater distance than this, and that is the distance from east to west, and you cannot conceive of another distance in the world which would exceed it, and we believe that one can measure it from one end of the populated area to the other.

If you start to go from the eastern edge to the western edge the measuring line between the person and the east continues to lengthen until he reaches the edge of the west, when he sets down the length of the measuring line between himself and the east, and can no longer go on. But if the one who had come to a standstill after reaching the western edge were to go beneath the earth and draw near the eastern edge, you would not find the distance of the populated area greater than the length of the rope between east and west.[5]

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4. עתות עמו I'm not sure of the meaning here, possibly should read עוונות עמו. (SI. p.15.)

5. The meaning here is that the length of the populated area equals the length of the ocean. (cf. p.12)

The breadth of the earth is not like this case, rather, if one were to begin to go from one side either towards the northern or southern extremities, he would not reach the end, either on account of the extreme cold or the extreme heat. Thus scripture states:

> "Have you surveyed the breadths of the earth? Declare, if you know all of it." 6

and it did not say "the lengths of the earth", to teach you that one cannot reach the end of the earth's breadth as one reaches the eastern and western extremities, which is the length of the earth.

If you see in secular books that it states that some country is so many degrees broad and its length is so many degrees or so many hours, and you ask: in what way did these wise men know the breadth and length of the countries in that they could say: The breadth of this country is such and such, and its length such and such"? I can tell you that they knew the breadth by the extent of arc which the sun declined mid-point in the sky 7 any day in the country whose breadth they were investigating,

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6. Job 38:18

7. i.e. on the celestial meridian of that place.

in the way which is explained in The Calculation of the Stars.[8] This is something easy for us in that discipline, and one can calculate it in whatever country one resides, at any time one wants to calculate the breadth.

However, the calculation of the length cannot be done at all times, because it is not calculable or manifested except at the time of a lunar eclipse, through a precise method which is not so incomprehensible; or at the time of a solar eclipse where its calculation is difficult and complicated, and one has to protect oneself in it from many sides, which one does not have to do during a lunar eclipse.[9]

The former kings who put their minds to determining this matter perfectly would appoint men who were learned arithmeticians, in every province to investigate this matter, and each one of them, at the time of the lunar eclipse would accurately determine the time at which the eclipse began and the time it ended. He would then keep these times with him, and, afterwards, they would all come before the king and check the differences in each man's

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8. Refers to another book by the same author ס'מהלכות הכוכבים which exists in the Vatican Library (Wolf I:53), possibly the same book as ספר השבון מהלכות, this according to Filipowski, SI p.xviii.

9. Solar eclipses are not visible on the whole of the hemisphere facing the sun. Secondly, the observer has to protect himself against sunblindness, and third, the solar eclipse is not always total.

calculation. If, for example, they found that the eclipse started in province A at 3 o'clock, and in province B at 4 o'clock and in province C at 2 o'clock, they would know that province A was a distance of one hour east of province C, and that it was a distance of one hour west of province B.[10]

In the same manner they could work out the difference of the end of the eclipse and know that their calculation was accurate, and if they found a discrepancy among themselves, between the beginning and end of the eclipse, they would know that there was some error in their calculations,[11] and they would go over the matter many times until they could be certain that there was no error. Such was the custom in all the countries. They began to investigate from the edge of the east until they reached the edge of the west, and they found the distance between them to be twelve complete hours and no more.[12]

The way you find the breadth and the length of the

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10. Of course the difference in hours could be translated into degrees of arc at the rate of 15° to 1 hour.

11. If the difference between two locations for the beginning was x, and the difference between the same two locations was y for the end, $x \neq y$.

12. 12 x 15°= 180°, proving bar Hiyya's previous assertion (p. 62.). It would be interesting to see where bar Hiyya derived this last piece of information.

of the countries is explained in the book The Shape of the Earth.[13]

13. Abraham bar Hiyya, The Shape of the Earth (ס' צורת הארץ). first published by Sebastian Münster with a Latin translation. 2nd publication by R. Jonathan in a collection called Salvation in Israel (ס' ישועה בישראל). Offenbach, 1720. cf. Filipowski. SI p. vii.

COMMENTARY TO THE SIXTH GATE.

Without overburdening us with the mathematics of the system, bar Hiyya gives us the basic make-up of what the early astronomers considered as the sun's orbit.

The first point that is brought out is that there is more than one heaven - actually eight, because the seven planets: Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn have their own distinct motion against the backdrop of the fixed stars in the celestial sphere (which is the eighth heaven, and whose motion is uniform). The celestial sphere can be divided into degrees of arc and even into smaller fractions, and since all the planets in their "heavens" appear against this backdrop, one can determine their positions exactly. This was discussed briefly in the commentary to gate two.

The sun has an eastward rate of progress against the backdrop of fixed stars in the celestial sphere. It comes up about 4 minutes after the celestial sphere has already made one complete rotation, every day. This corresponds to an eastward progress of just less than 1° (bar Hiyya is more accurate at 59'8") a day. This is, of course, above the sun's daily (diurnal) revolution with the celestial sphere which in reality represents the earth's rotation.

It was early noted that the sun's apparent orbital speed and distance from the earth vary slightly during the

course of a year. We now know (since Kepler's New Astronomy, 1609) that the reason for the changes in orbital speed and distance are due to the elliptical nature of the earth's orbit.

The sun - earth system outline by bar Hiyya is similar to the one first outlined by Hipparchus (fl. 160 - 127 B.C.), the greatest of the Greek astronomers. Since the earth's orbit around the sun is very nearly a circle, making the earth stationary and the sun mobile and having the centre of the sun's orbit non-coincidental to the earth's centre, made for a pretty accurate accounting of the phenomena.

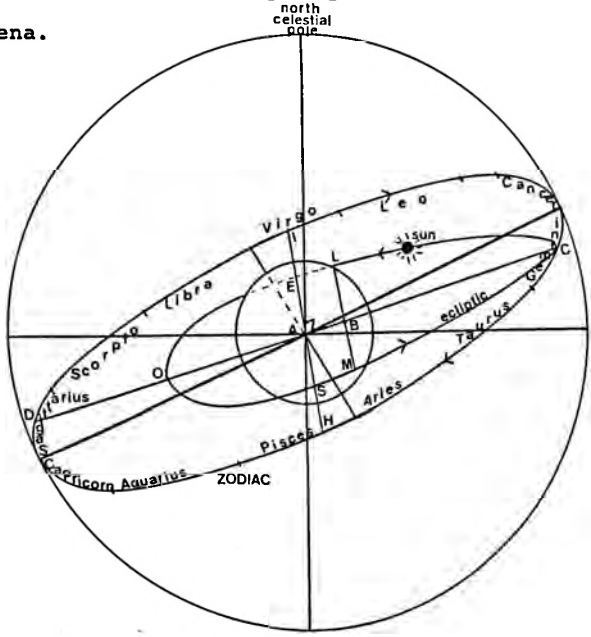

Fig. 6:1.

Fig. 6:1 is an attempt to show the figure in the text on p.89 represented as it was conceived "in reality". Remember the sun's path, (the ecliptic), is in the same plane as the zodiac. The whole celestial sphere turns on the axis of the celestial poles in a westward direction.

As bar Hiyya explains, the reason that the sun appears to change orbital speed and distance, is due to the parallax when its motion is observed in relation to the fixed stars. Although the sun really moves at a fixed rate, the fact that its orbit has a centre non-coincidental with the earth's centre, means that at times it appears to move through 180° when in fact it has moved through 184°. Since its movement is constant, it will take a shorter time to move through the remaining 176° of its orbit, yet to us will appear to have traversed the remaining 180° of the zodiac. Thus the former traverse will appear to us as having taken longer than the latter.

bar Hiyya closes this section showing how the preceding accounts for the population distribution being concentrated in the latitudes between 16° south and 66° north. In the north, when the sun is in the southern constellations, i.e. autumn and winter, the sun is nearing its perigee, or closest point to the earth. Thus the proximity to the earth mitigates the cold. However, above the latitude 66° north, the area is still too far away from the sun and therefore the cold is unbearable. In the summer, the sun is at its

apogee, or furthest distance from the earth, thus mitigating the intense heat. On the other hand, in the south, the summer marks the point of perigee, and the heat becomes too intense to withstand.

THE SIXTH GATE.

Explains the course of the sun in which days and nights change in length.

Know then, that the main heaven which covers over all the heavens from above and below,[1] or which veils them or shields them, in whatever way you wish to denote it, is the eighth heaven divided into 360° and every one of the heavens within it is similarly divided into 360°. Every one of these degrees in each heaven is divided into 60 parts, and they are called minutes, and each minute of them into minutes of a minute or, if you prefer, second minutes. Similarly, the seconds into thirds and the thirds into fourths. This is not because the heavens have these divisions, since there is no division in the heavens at all; rather, we divide them up so as to be precise about the calculation of their motion and the motion of the stars upon them.

The celestial sphere, rotating from east to west, makes a complete rotation in approximately [2] a day and a night, and the sun and moon move in their heavens from west to east - in the opposite direction to the motion of the

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1. The 8th heaven, in other words, was an all encompassing sphere - this is what we call the "celestial sphere".

2. It actually takes a little less (approximately 4 minutes) than a complete day and night. cf. comment on second gate p. 23f. "The Noon Meridian".

celestial sphere, but they do not move at the speed with which the celestial sphere moves. The sun moves across the celestial sphere[3] 59'8"[4] and a few more thirds and fourths which we do not need to specify, and traverses the whole celestial sphere in 365 days and a quarter, less a little. Consequently, the celestial sphere continually rotates every single day what the sun traverses in one year.[5]

The celestial sphere rotates around the centre of the earth and its motion in one day does not exceed its motion on another day. The motion of the sun is not the same, but it travels around the heaven in which it makes its revolution at the rate of progress equal to the rate which we mentioned to you, viz. 59' and the additional parts of a minute, and its actual motion does not exceed on another day nor is it diminished, but to us it seems that it alters its rate of progress. At times it moves at a slower speed than its uniform motion, at times it moves at a medium rate, equal to its uniform motion, and at times it moves at a greater speed than the uniform rate. It

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3. Against the backdrop of fixed stars.

4. (SI. p.16.) The text reads fifty-eight, should be 59.

5. It takes the fixed stars a little less than a day to make a revolution westward around the earth, but the sun takes $365\frac{1}{4}$ days to make the one revolution from west to east around the fixed stars of the celestial sphere. (see p.28. on the Ecliptic.)

appears that this divergence in its motion occurs because the centre of the heaven on which it revolves and the centre of the earth are not coincidental, but the centre of the heaven is displaced from the centre of the earth by about 2° in 120° along the diameter of its heaven.[6] Owing to this, you do not find that all the parts of the heaven are the same distance from the centre of the earth, but you find one part which is furthest of all.

When the sun is at this part, it is at the point of its apogee and maximum altitude. Corresponding to this, there is one part which is closest of all and when the sun is at this part, it is at the point of its perigee and minimum altitude. As for the two sections at the centres of the two sides, on this side and that; when the sun is in them, it is at an intermediate position. They are called the points of intermediate altitude, because this altitude is less than the maximum altitude by as much as it exceeds the minimum. When the sun is at its minimum [7] altitude or on either side of it up to the intermediate altitudes and appears to be moving at a speed greater than the uniform rate, it really has not increased nor diminished its speed.

I will add an explanation for you on this matter

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6. SI. p.16. See fig. p.89. I am not sure what the 120° refers to.

7. SI. p.16. This reads "maximum" (גדול), yet this contradicts the rest of the gate!

and say, that when the sun is at its point of greatest altitude, it is at the limit of its distance from, and elevation above the earth, and it moves at the lowest limit of its speed. When it revolves from the point of its greatest altitude, it turns to descend to the intermediate altitude and it decreases its slowness,[8] and increases the rate of its motion until it reaches the intermediate altitude, when its motion in that place corresponds to its uniform motion, and from here on, it exceeds the uniform motion and increases its speed until it reaches its minimum altitude. Here it moves at the highest limit of its speed just as at its maximum altitude it moved at the lowest limit of its speed. When it revolves from its minimum altitude, it directs itself to ascend to the intermediate altitude and it decreases its speed and diminishes the amount of its motion until it arrives at the point of intermediate altitude on the other side. There it moves at the uniform motion and from here on, it lessens its motion from the uniform motion and slows down its motion until it reaches its maximum altitude.

Its maximum altitude is in Gemini, while its minimum altitude is in Sagittarius. One of its intermediate altitudes is in Virgo and from here the sun descends to its minimum altitude. The other is in Pisces and from here

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8. i.e. it increases its speed.

the sun ascends to its maximum altitude.

We give you a figure so that you can visually perceive the details of the changes in motion. Moreover, you will understand for what reason the cold deters settlement in the northern extremity, while the heat deters it in the southern extremity. In this figure we have described a circle whose centre is the centre of the earth. This circle represents the zodiac. At its centre is point A, and at its four cardinal points C, D, H and I. This circle is divided into four equal parts by two lines which pass through its centre at right angles. At the ends of the one line are C and D, and at the ends of the second, H and I. Each one of the four measures 90°, since a complete circle is divided into 360°. Point C is midway through Gemini, and point D, midway through Sagittarius, point H, midway through Pisces, and point I, midway through Virgo.

Within this circle we inscribe a smaller circle, whose centre is outside the centre of the earth, a distance from A, in the direction of C, a distance of 2°. This centre is point B, on the line CD. This circle is the sphere of the sun's heaven. At its centre is B and at its four cardinal points, C,M,O and L. The point O, on the line CD, lies in line with point A. We draw another line through point B at right angles, which is MBL.

The circle is divided into four equal parts, each part 90° of the ecliptic. At the beginning of the first

part is C, and this is the point of maximum altitude touching the curve of the zodiac. The second part is M, and this is the first point of intermediate altitude, the third part is O, and this is the point of closest altitude, the fourth is L, and this is the second point of intermediate altitude.

You find in this little circle that the line of the earth's diameter, which is the line IH, divides it unequally into 360°. The first [9] is the arc ELCMS, which is greater than the semicircle of the ecliptic. This arc is surrounded by only half of the zodiac. This is the arc ICH which extends across six of the constellations, from midway through Pisces to midway through Virgo. The second part is the arc EOS, which is less than half the ecliptic. One complete half of the zodiac surrounds it, namely the arc IDH, which contains six of the constellations, from midway through Virgo to midway through Pisces.

At the moment when the sun is at point S of the curve of the heaven, all the inhabitants at point A, which is the centre of the earth, see it at point H of the zodiac, which is midway through Pisces, which is the intermediate distance. When it is at point C, it appears to them midway through Gemini, which is its greatest altitude. It appears as if it moved only through three constellations, yet it

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9. Apparently the first half.

moved through the whole arc SMC of its heaven, which is greater than a quarter of its heaven. When it is at point E of the sphere of its heaven, it appears to be at point I, which is midway through Virgo. You will find that it moves about 184° from point H of the celestial sphere to point I, which is a movement of about $182\frac{3}{4}$ days, and it only traverses 180° of the constellations and because of this it appears to move slowly.

The converse of this matter is when the sun moves across the sphere of its heaven from point E through point O to S, which is about 176° of its heaven.[10] It makes this movement in about $178\frac{1}{2}$ days, and it appears to have moved through the whole arc GDH of the zodiac, which is six complete constellations, viz. Midway through Virgo, Libra, Scorpio, Capricorn,[11] Sagittarius, Aquarius and half of Pisces. Here it appears to move swiftly, according to this figure.

You see in this figure that when the sun is at its maximum altitude from the earth, it is at point C of the sphere of its heaven and on either side of this point it appears to move in the constellations of Gemini and Cancer. Similarly, it is at minimum altitude above the earth, when

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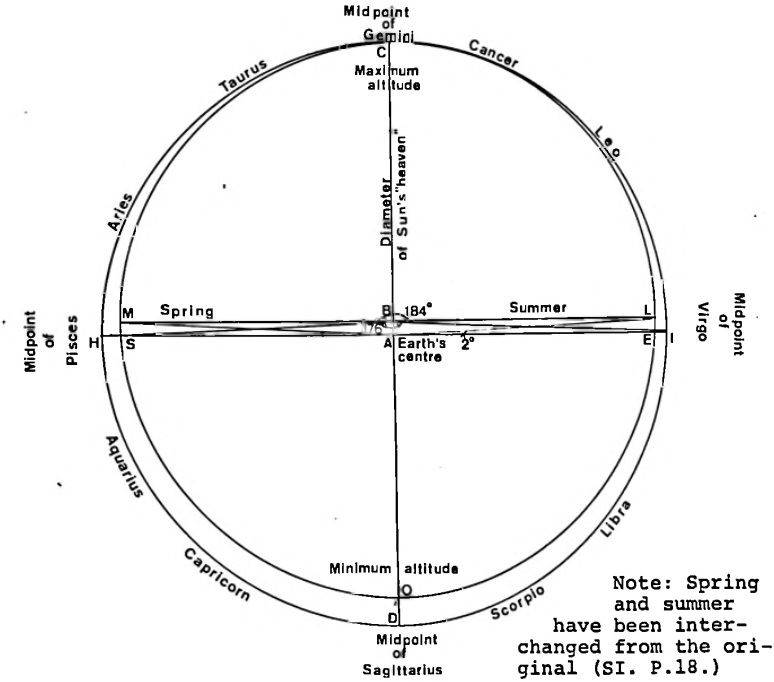
10. The text (SI. p.17), makes no sense if left as רקיע, celestial sphere, therefore read רקיעה, its heaven.

11. (SI. p.17.) Capricorn has been omitted from the list.

it is at point O of the sphere of its heaven and on either side of this point it appears to move in the constellations of Sagittarius and Capricorn. You find that when the sun is in the constellations of Gemini and Cancer and the constellations directly preceding and following them viz. Taurus and Leo, it moves in the northern part of the zodiac.



Note: Spring and summer have been interchanged from the original (SI. P.18.)

It inclines in its orbit towards the inhabitants of the north and revolves above the heads of the inhabitants of the north, warming the air in all these parts. You will thus

find warmth in all the inhabited places of the north during the days in which the sun moves through these constellations which are north of the celestial equator. However, the sun is at the limit of its maximum altitude from the earth and on account of this the heat in the north does not become extreme.

When the sun is in the constellations of Sagittarius and Capricorn and the two constellations adjoining them, it moves towards the south and draws away from being opposite the north.[12] You will find coldness in their lands during these days, yet it does not overstep the limit because the sun is at a closer distance to the earth, which decreases the cold. You will find, in the case of the northerners, that if the heat comes upon them on account of one factor, you find corresponding to it another factor which diminishes it, while if the coldness comes on account of one factor, another factor will occur which will weaken it. On account of this, the inhabited area stretches northward until the sun reaches too great a distance from there and its light is witheld from them for more than 24 hours. The cold would then overpower them and the strength to subsist becomes enfeebled, since heat is only found in light. Consequently, the inhabited area in the northerly direction ceased at a latitude of 66°

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12. The angle of declination of the sun from the zenith in the north increases.

However, in the southerly direction this is not the case, rather, when the sun is in the constellations of Sagittarius and Capricorn and the two constellations adjoining them on either side, it moves in a southerly direction and draws nearer in its circuit to a point above the inhabitants of the south and warms their air. When it is in these constellations, it moves in its heaven through the arc which is close to the earth, viz. the arc SOE. This aspect increases the heat and thus the heat towards the south is found to accrue on two accounts, each one of which increases the heat and makes it overpowering. On account of this, the settled area in the south only reaches 16°, which is the distance of the mid-points of the constellations of Scorpio and Aquarius from the equator.[13] These constellations are not so far from the intermediate altitude. For this reason, the settled area in the south reached a point opposite them.. From here on the sun draws closer to the earth and moves deeper south. These two aspects increase the heat until it is impossible for animals to withstand it, and the southern settled area is cut off from here and on. You can see from this that the heat prevents settlement in the south, while the cold prevents it in the north, as we mentioned to you above, and the motion of the sun's course and a few of the phenomena

13. cf. fig. 2:7a (p.28.), and note that 16° south bisects the constellations of Aquarius and Scorpio!

connected with it have been made clear to you.

COMMENTARY TO THE SEVENTH GATE.

Since the Jewish calendar deals with lunar months, bar Hiyya is constrained to give a brief explanation of the moon's motion. The explanation itself is clear and simple and we will confine ourselves to filling in a little background. More complicated technical matters are elucidated in the footnotes accompanying the text.

As in the case of the sun, bar Hiyya's outline of the moon's motion follows that of Hipparcus (cf. p.79.). Since the moon suffers from the gravitational attraction of both earth and sun, its motion fluctuates even more than the apparent fluctuation of the sun. The early astronomers, believing that the actual motion of the planets was uniform and could be represented in circular motion (because the circle was a perfect shape), accounted for the fluctuations by means of an ingenious system of epicycles - called by bar Hiyya, if we were to translate him literally, "supporting sphere" (deferent) and "sphere of revolution" (epicycle).

It is a moot point as to whether bar Hiyya really believed the moon to travel in the path he describes. The text seems to imply it:"Actually its motion is composed of four motions, (p.95.) and "... this is indeed the way this revolution takes place and this is its configuration," (p. 99.). However, Ptolmey (fl. 140 AD.) did not claim that this was the actual path of the moon, merely a system by which the moon's position could be established, and one can

assume that if bar Hiyya had not read Ptolmey in the original, his Arabic sources would have utilized him.

bar Hiyya elucidates the puzzling text of b.Rosh Hashannah 25a (see p.102f.), which also is meant to prove the point that our early rabbis were aware of astronomical science.

The point of the whole chapter is explained in the closing paragraphs,where an explanation is given of the lunar month. Since the moon completes its revolution of the heavens about 13 times faster than the sun, in the course of one solar year it completes approximately 13 revolutions - actually a little more. The year starts when the moon is first in conjunction with the sun (i.e. between the earth and sun). For an observer on earth, the moon would be lying along the same meridian as the sun and not necessarily at the same point, since the orbit of the moon is inclined to the ecliptic. Thirteen completed revolutions to where the sun is, would be twelve lunar months - the twelve intervals "in between". Thus bar Hiyya gives us some conception of what a lunar month actually is.

THE SEVENTH GATE

In explanation of the moon's motion.

The moon moves uniformly in its heaven each day in a manner similar to the sun's motion: from west to east. However, its motion is greater in extent than that of the sun [1] and it differs from it in other ways with regard to motion. It only resembles it concerning direction of motion which is from west to east.

The moon's motion is composed of two motions in terms of the narrow scope of this treatise, so that the student can understand it. Actually its motion is composed of four motions [2] which we are not constrained to explain here. This motion is based upon two spheres: the one sphere encompasses the earth like the remainder of the heavens, and its centre is the centre of the earth; the second sphere

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1. The sun moves east about 1° in a day. The lunar month is 30 days, this is the time it takes from one conjunction with the sun to the next. (A body is in conjunction when it lies in between the earth and the sun.) In 30 days the sun has moved about 30° along the ecliptic. In other words in order to get one conjunction to the next, the moon has to move 360° + 30° = 390°. Hence we can say that the moon moves $\frac{360}{30} = 13$ times as fast as the sun.

2. The greatest number of circular motions I have been able to find thus far for lunar models is three.

is a minor sphere which is attached to the first sphere which was larger than it, and its centre is on the circumference of the first sphere. Consequently half of this sphere lies outside the circumference of the first, and the remaining half within the circumference.

The first sphere is called a "sphere which resembles the zodiac" in that its centre is the centre of the earth. [4a] The second, minor sphere, is called " the epicycle" [4b] because the moon itself is located on this sphere. The centre of the epicycle revolves along the circumference of the deferent which resembles the zodiac. The latter revolves upon it[5] from west to east and together turns the epicycle through 13° in 360 of the deferent [6]

4.a (SI p.19.) Perhaps should read אשר מרכז שלו הוא מרכז ההארץ, inserting the words מרכז שלו. This is also called גלגל הסובל, lit. supporting sphere, and which we have chosen to translate as "deferent".

4b. (SI. p.19.) Heb. גלגל ההקפה, lit. sphere of revolution.

5. (SI. p.19.) Lit. "the supporting sphere which resembles the zodiac." We read סובל for סובב.

6. The zodiac.

and about an additional 11 minutes of arc each day. The moon itself revolves on the circumference of the epicycle: from east to west, if its body is in the exterior curve of the sphere, and if its body lies on the interior curve of the sphere it moves from west to east. This motion is 13° in 360° of the epicycle, and an additional 3 minutes in 60 and few seconds more, each day.

You will find that when the moon travels on the curve of the epicycle which is interior to the resembling sphere [7], its motion together with the motion of the centre of its sphere are both in the same direction, and the two motions are combined together and the moon appears as if it is moving swiftly; and when the moon travels on the exterior curve of the sphere, the motion of its body is in one direction while the motion of the centre is in the other direction: its body moves towards the west while the centre moves towards the east, and its motion decreases [8] the motion of the centre and the moon appears to be moving.

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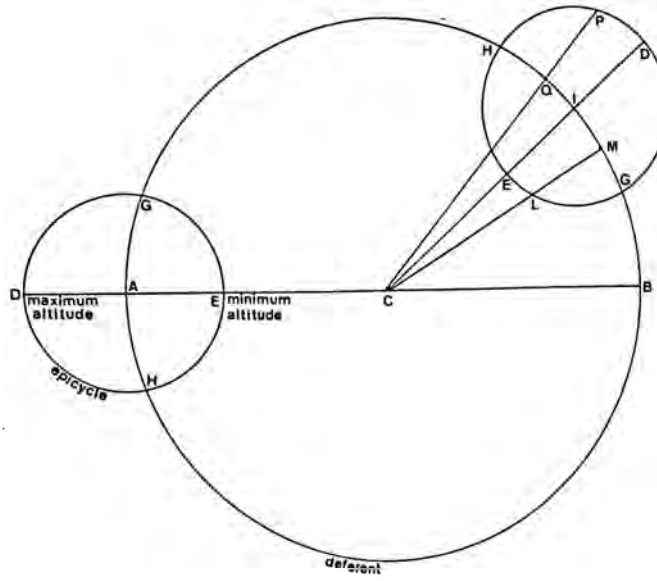
7. the sphere which resembles the zodiac. i.e. the deterent.

8. The combination is less than the actual motion of the centre.

Here is a figure for you so as to show you this matter. I describe a large circle corresponding to the lunar sphere which resembles the zodiac and at the two ends of the line which bisects it, two points A and B. At the centre of this line is point C which is the centre of the circle which is the centre of the earth. Again I describe a minor circle at point A on the circumference of this circle and half this sphere lies outside the circle while the second half lies within the circle. Extend the line AB, which bisects the deferent and let us lengthen it until one reaches the outside curve of the epicycle at



point D, and at the point where this line crosses the inner curve of the epicycle is point E; at the two points which lie on the circumference of the deferent which divide the epicycle are, at the one point G and at the other H. You can consider in this figure that point D which lies without the deferent is the moon's maximum altitude and point E which lies within the curve is the minimum altitude.

The centre of the epicycle revolves along the circumference of the deferent from point A in the direction of G from west to east. The moon, itself, is sometimes at point D which is the maximum altitude, and sometimes at point E which is the minimum altitude, and it appears at these two points as if it is at point A of the heaven of the deferent which resembles the zodiac and which is the point which is the centre of the revolution.

You see in this figure that if the moon is at point D, which is without the circumference, it moves in the opposite direction to the motion of the centre which is in the direction of G, while the moon itself travels toward point F, and if the moon is at point E, which is within the circumference, it moves in the direction of the centre point's motion, for this is indeed the way this revolution takes place, and this is its configuration.

If we revolve the centre A along the circumference of the deferent in the direction of G until the

centre reaches I, and we describe a circle around point I as the epicycle, the shape it was at A, the moon itself which was at point D, the maximum altitude, revolves towards point H and reaches point B of the epicycle. It appears in the heaven of the deferent at point Q[9] and the position of the centre is at I. The arc through which the centre revolves is from A to I and on it in this figure are written AGHQI. The moon which has reached point P of its epicycle appears in the deferent at point Q because the line from the centre of the earth, or from an observer on it, to the moon, is the line CPQ. This reaches the moon at point Q, but he sees it at point P of the deferent. The apparent arc which is described by the moon's motion is traced on the deferent as AGHQ. You will find the position of the moon to be less than the position of the centre by the arc IQ [10], and thus the moon's journey appears to be diminished from its mean motion and traveling slowly.

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9. Once again the parallax is what causes the apparant fluctuation of the moon's motion, according to this theory.

10. The moon appears to have progressed along the arc AGHQI. which is less than the progress of the centre of the epicycle. To wit: the moon itself appears only to have progressed to Q, while the centre of the epicycle has progressed to I. Consequently, the difference will be the arc IQ.

If the moon itself is at point E, it will be traveling towards G and reaching L on the curve of the epicycle, the moon appears on the line CLM at M which lies on the cirucmference of the deferent. The arc which appears to be traced out by the moon's motion is the arc AGHQIM and the arc of the centre's motion is the arc AGHQI. You will find here that the moon's motion is greater than its mean motion and travels swiftly.

You can deduce that the moon's motion alters in three ways, although the centre of the epicycle [11] moves in all cases at one rate [12] viz: the arc AI. Sometimes it travels at its speedier rate such as the arc AM, sometimes it travels at its slower rate e.g.the arc AQ, and sometimes it travels at its uniform rate, which resembles the arc AI. You find that its speedier rate is greater than its slower rate by an arc of MQ.

To this effect, our rabbis, of blessed memory, said:

> "Rabban Gamliel said to the sages: 'Thus I have received a tradition from my grandfather's court sometimes it takes longer, and sometimes it takes shorter.'" [13]

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11. (SI p.21) It makes more sense to read גלגל התקפה - epicycle, than גלגל המסובל - deferent.

12. (SI. p.21) read מדה for מזה.

13. b.Rosh Hashannah 25a.

The preceding was the explanation of "longer" and "shorter".

You find that the moon's motion overlaps that of the sun a great deal, and is 13 times greater than the sun's motion. You find that when the sun has completed its revolution of the celestial sphere one time, the moon will have completed its revolution in it 13 times. During these times it draws close and reaches the sun's position 12 times in the course of its additional number of revolutions in which the sun has completed one revolution.

I have not needed to go into a lengthy explanation of these matters in order to reach its conclusion because I do not intend here to investigate the motion of the celestial sphere and the motion of the stars and explain their exact motions. Rather, I decided to discuss a brief part of this according to the needs of this treatise which depend on astronomy. With this I close this gate.

COMMENTARY TO THE EIGHTH GATE.

The final three gates of the introduction deal with the smallest unit and fractions of this unit, which one needs in order to set up a calendar viz: the day. Now that the basic physical concepts have been introduced, the use of these concepts with regard to time can be clarified and once our unit is made clear, the actual process of calendation can be elucidated in the next two essays.

It is interesting to see that even since early times, the word "day" (Heb.יום.) has had a variety of meanings concerning time. However, as behooves a text of a technical nature, bar Hiyya must define his terms especially where usage has blurred precise connotation.

Of the possible meanings of day:

1) specific time - during day or night, p. 104
2) now, p. 104
3) certain time, neither fixed nor known, p.104f.
4) light, p.105
5) period from dawn to appearance of the stars, p.105f.
6) period in which sun is visible i.e. from sunrise to sunset, p.107
7) 24 hours, p.108

bar Hiyya choses 6 and 7 alone to use in his treatise. We now have two specific meanings of day.

THE EIGHTH GATE.

In explanation of the term "day" as to the several meanings it has in the Holy Tongue, and which meaning we need in his treatise.

Know for certain, that the word "day" has many meanings in the Holy Tongue. I will explain those which I have come across.

There are times when it is said with reference to a specific time which happens to occur to a person, whether day or night, as is written:

> "And it came to pass on a certain day, when he went into the house to do his work..." [1]

i.e. when (my italics), he happened to come, whether it was day or night.

Sometimes its implication is of "now", as is written:

> "Swear to me as of today." [2]

whose implication is, "Swear to me now."

Sometimes, about a certain time which is not fixed at a known time, as is written:

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1. Gen 39:11 "ויהי כהיום הזה ויבא הביתה לעשות מלאכתו"

2. Gen. 25:33. "השבע לי כיום".

"And it shall be on that day, in the day when Gog shall come."[3]

"And it shall be on that day," is an expression which is neither used for a known day, nor for a recorded time, but for a time which the Holy One, Blessed be He, will reveal in His mercy.

There is a place where it refers to the actual light, as is written:

"And God called the light day..."[4]

He called it day before He illuminated the earth, because the earth still had not appeared and its location was not known, nor was it called "earth" until the third day. Throughout the whole chapter the time of the light is called morning, and the time of darkness, evening. They are not called day and night, so as to teach you that the light itself is what is called day at the beginning of the chapter.

Sometimes it is said with respect to a measurement of time during which the light continues to be caught[5]

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3. (SI p. 22) Ezekiel 38:18. (יחזקאל לח,יח;לט,יא) should read (יחזקאל לח יח), and the words "והיה ביום ההוא" should be included at the beginning of the quote and following. The verse as in Ezek. 38:18 and as ammended reads "...והיה ביום ההוא ביום בוא גוג; והיה ביום ההוא"

4. Gen. 1:5 refers to the creation on the first day.

5. i.e. twilight - certainly this phenomenon is in fact caused by the earth's possesing an astromical..

in the world's air, when the sun itself cannot be seen. This is from the beginning of the dawn [6] to the appearance of the stars. The dawn is nothing other than the light of the sun which remains caught in the air close to the earth, which is drawn into the clouds which ascend from the earth.[7] Thus the stars do not appear or become visible until such a time as the light is separated from this dense air. Scripture called this whole period of time "day", as is written:

> "...so that in the night they may be a guard to us, and may labour in the day." [8]

Our rabbis of blessed memory relied on this matter concerning all commandments which a man is obliged to perform at night so that they would be performed during the actual night, and not just when it was apparent,[9] but without any doubt. In other places, they, of blessed memory, make obligatory while it is still daylight, when they rule with stringency regarding the commandments, saying that one adds from the profane to the holy, and they count as the

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6. (SI p. 22) from the beginning of dawn- מעלות השחר

7. An ingenious explanation based on reflection of the light in the atmosphere and clouds.

8. Neh. 4:16 Verse 15 reads "So we wrought in the work: and half of them held the spears from the rising of the morning (dawn) till the stars appeared."

9. (SI p.22) דוגמא peculiar use, meaning "apparent," opposed to "true" night.

night the period before twilight.[10] This additional element is nothing but the afterglow of the sun. But from nightfall, which is the time of its setting, all agree that this marks the festival or the sabbath, without any doubt, and here there is no additional part. The additional part is all that you add upon yourself through stringency, while it is still day.[11]

Just as in this case there is an additional element, so there is an additional element or deficit, if you prefer, at the beginning of what they count as the night from when the stars start to appear. From this you deduce that the exact measurement for a day which has neither an additional element, nor a deficit, is from the time the sun rises in the east until it sets in the west. The night is from the time of its setting in the west to the time of its rising in the east as is written:

> "The greater light to dominate the day and the lesser light to dominate the night." [12]

During the whole time that the sun shines over the earth, the light [13] of the moon has no strength to spread over

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10. i.e. one takes the dusk from the secular day and adds it to the holy day which follows, so that it starts before the stars appear.

11. Although the actual festival or sabbath may only start at nightfall, the period before, during the dusk, is a matter of whether one wishes to be strict in one's observence.

12. Gen. 1:16

13. (SI p.22) For כאור read באור.

the earth even when it is full of light,[14] because it has no domination during the day. If the sun sets, you immediately see the light of the moon illuminating the earth and spreading over it, and if it is full of light, its light lasts until sunrise because its domination is only during the night. From this you have proof that the beginning of the night is from the time that the sun sets, and the beginning of the day is from the time of its rising.[15]

Sometimes "day" is meant to refer to both these times i.e. day and night so that the two of them conjointly are called day, as scripture has it:

> "Thus evening came, and morning - first day." [16]

You can see from this verse that day and night together are called day. If you find us saying "day" in this treatise, know then, that we are saying it in one of these two respects: either the timespan that the sun is above the earth, from the time of its rising to its setting which is called "day" and has a corresponding night; or day and night

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14. Maximum brightness, or full moon.

15. Because the moon can no longer cast its rays once the sun rises and the verse from Genesis stated that the sun ruled during the day, and the moon at night, therefore, the day is from sunrise to sunset or the period when the moon's light is not as powerful, while night is the period in between, when the moon casts its rays.

16. Gen. 1:5

conjointly which are called day.

We will not use it in one of the former meanings since for the most part, it is used for a specific example, or as a figure of speech. In our context we only require these last two meanings and we draw a logical inference from these two meanings. I should point out that scripture has called light, day, and we only find light in this world from the sun, and at whatever time the sun is visible, light is found among us. We call that time day because we see light spreading over the earth. We designate as night, the time that this light is hidden from us. However, as for this time that is called night, even though the light is not visible to us, it is known that the sun illuminates another place or passes under the earth and shines on the waters which are under the earth and it is day for that place. Thus the light of the sun occurs at night and if it is missing from one place, it can be found at another. Thus according to this logical inference, they designated these two periods conjointly as day. [17]

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17. bar Hiyya is showing that scripture, in using these last two meanings of day, is actually being consistent with its primary meaning of light. "Day is as long as there is light on the earth" can be taken in the local and general sense. Locally, it means the period of time in which the sun is continuously visible at one place. Generally, it means the 24 hour period, during which light is spread around the whole world, by the sun.

You find that day is used in general and particular senses. In its general sense, it refers to the period of time during which the light begins to appear over the earth and completes its whole journey above the earth and below until it returns to its place of original appearance. During this period of time its light will have completed spreading over the earth above and below. This is "day" used in its general sense.

In its particular sense, it is used in every place over which the light of the sun spreads, as long as its light is spread over that place and is not spread over another. In this place it is called day and in another, night.

COMMENTARY TO THE NINTH GATE

After introducing the nature of the problem viz: at what point does one begin a circular motion like the day, bar Hiyya enumerates four possibilities. The discussion here can be divided basically into three parts. First, bar Hiyya explains the astronomical position which is, to start the day either at noon or midnight. The reason for this, he explains, is that the time from one point to the other is always exactly 12 hours whereas sunrise and sunset can vary in time in the course of the year and depending on one's latitude. However, though this method may work for astronomers, it is not clear enough for everyone's use.

Next, bar Hiyya discusses the Christian position, which starts the day in the morning. He put forward several arguments in favour of this position, but finds arguments against each one from the Jewish viewpoint.

Lastly, he gives the Jewish position, which is to start the day in the evening. He uses both "logical" and scriptural proof to establish this position.

One might ask why bar Hiyya finds the apparent necessity to go to such lengths to refute the "Christian position". It seems quite possible that he had to find counterarguments because on the surface, starting the day in the morning really does make more sense, since this is the beginning of one's activities. It is possible that many

Jews also felt the "sensibility" of starting the day in the morning and so bar Hiyya had to demonstrate why starting the day in the evening was both logical, and in keeping with scripture.

discusses the disagreements among the nations as to the beginnings of the day and according to whose opinion we assign its beginning.

The day, in its broader sense, behaves, as to its measurement, in a revolving circular manner, in that it begins from a certain place and continuously revolves until it reaches the place whence it began. Whereupon it again behaves in its revolving fashion without stopping. You cannot find in it a certain place which would be suitable to be called the beginning for everyone. Whatever a person considers appropriate he designates as its beginning in as much as there is no given beginning to a circle. Whatever place you begin from, you assign as its beginning and thus this has become the fitting practice nowadays.

However, when we reflect about the day in a precise manner, we find that there are four moments which are suitable to be designated as beginnings, or starting points of the day, because during such times the sun is directed to one side or the other in its revolution around one place, and only at stages like these does it change the direction of its motion and even though it may not change its direction of motion in respect of its revolution around the whole earth, it changes its direction of motion at a particular place.

The first such moment is the time of its rising because it begins to rise above the place over which it

shines. The second moment is the time when it is midway through the sky because at this place, it reaches its maximum altitude and elevation over the place above which it rose, and from here on, it inclines to the west. The third moment is the time of its setting because it begins to go beneath the earth and to be hidden from the place over which it shone. The fourth moment is the time when it is midway through the sky underneath the earth, because from there it begins its ascent above the earth and is about to rise above the place whence it set.

We have found that the nations and skilled people capable of calculating days and nights began to assign the beginning of the day to each one of these four moments according to each one's opinion and according to each one's needs.

Of them, the ones who speculate in the calculation of the motion of the stars and who investigate the extent of their movements need to investigate the amount of motion each star has in one day. These designated the beginning of the day as either from the time the sun was midway through the sky above the earth viz: noon, or at the time it was midway through the sky under the earth viz: midnight.[1]

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1. They knew when the sun was at their meridian or 180° from their meridian.

They said, "We are unable to fix the beginning of the day from one place because days and nights are not uniform throughout the world,[2] except if you join a certain night to the preceding day will the two obviously comprise one day. However, their lengths will not be uniform, because the day preceding the night is either longer or shorter than the day after it, and were we to plot the motion of the stars by days whose beginning were either the risings or settings of the sun, and were one us to begin to plot them from one sunset to the next,[3] we could not all come to a consensus, on account of the disparity between days and nights.[4] Consequently this investigation would throw us into error.

"But now, when we investigate them either from noon or from midnight, we always come to a consensus, because the uniformity which is found in them occurs in this way: if you link one noon or midnight to the next one, you link in the same way, whether before the former or after it,[5]

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2. They depended on local time and could not standardize the time to that of one location.

3. (SI p.24) read אחר for אחד.

4. A calculates the movement from sunrise to sunrise, B calculates it from sunset to sunset. Since B's second sunset could either be more or less than 12 hours after A's second sunrise, the earth and planet have had a greater or lesser amount of time in which to move, and the results of A and B will not coincide.

5. The point is, that noon is <u>always</u> 24 hours after noon and the following midnight <u>always</u> 24 hours after midnight, no matter when the sun rises and sets. This should be evident from gate three.

you will not find that the first day exceeds the next, nor is less than it." This is the normal procedure every day for if half the day projects into half the night on this day, you will find on the second day [6] the situation reversed: half the night projects into half the day; so that the two of them always make up 12 full hours, for the movement of the sphere from the meridian[7] above the earth to the meridian underneath the earth is equal to its movement from the meridian beneath the earth to the meridian above the earth in all populated areas. But the extent of its motion above the earth is not the same as its motion beneath the earth but at times exceeds and at times is diminished."[8] According to this circumstance, you find all who calculate the motion of the stars assign the beginning of the day in their calculations to either noon or midnight; the computation can only be standardized for them in this way.

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6. The point of this seems to be that it takes 12 hours exactly for the sun with the celestial sphere to move from the meridian (noon) to a point 180° distant (midnight), and exactly 12 hours for the sun to retain the meridian, no matter when sunrise or sunset occur. cf. the figures in the commentary on gate three.

7. SI p. 24) מחציח השמים lit. zenith; here we interpret it as meridian since the sun certainly does not always attain the zenith.

8. This was discussed in gate three, where it was shown why the sun sometimes takes longer or shorter than 12 hours to traverse the sky above the earth.

These people acted according to the dictates of their discipline, and we are not constrained to rely on them nor to follow them, because noon and midnight are not something self-evident or clearly understood in the minds of all, rather, a person can only ascertain it exactly during the day by means of an astrolabe [9] or through a sundial or measuring instruments which empty water or sand and all instruments which are made to determine hours or to assess the actual position of the sun above the earth. It cannot be ascertained at night except through the measurement of vessels which empty water or sand and suchlike or with instruments which determine hours or by assessing the position of one of the stars which light up the night sky.[10] Every one of these things is only usable with the skill which one person may have acquired but not another, and we require that the beginning and end of the day be obvious and well known to anyone so as to befit all their needs in this world.

The only moment you can find during the day which is self-evident and widely known to everyone are these two moments, viz: the rising of the sun in the east, or its setting in the west, and it is fitting to designate one of

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9. (SI p.24) משקל, astrolabe. A string with a weight attached to the end would mark out the angle of the sun on the protractor. The use of this word is uncertain.

10. If we know what stars are 180° to the sun, midnight would be the moment when these stars crossed the local celestial meridian.

these moments as the beginning of the day.

We find that the Christian nation and all those who observe its customs, begin to calculate their days from one sunrise to the next. They say that the day must precede the night following it, for day is more laudable than darkness and it is fitting for the laudable to take precedence. Moreover, the Holy One Blessed be He created the light first and with it he initiated His whole Creation, and with the existence of light, day came into being and from this time and on, days and nights began to be counted. Thus scripture states:

> "Day is Yours; Yours, also, the night."[11]

"day"before"night." Moreover, it is written:

> "Day to day utters speech and nightly knowledge is revealed."[12]

Just as the day precedes in this case, so speech precedes knowledge, and a man does not know anything if he has not been told. Thus a verse states:

> "...or by day and by night, when the cloud lifted, they journeyed."[13]

In this a full day was counted and it began with the day and attached the night to it. This shows you in every case that the day precedes the night and that it is worthy of being counted first. On these and similar arguments those who

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11. Ps. 74:16

12. ibid. 19:2

13. Num. 9:21

begin to count from the sunrise base their position.

We carefully consider their arguments and examine their words, and begin with the proofs which they brought from Holy writ, to which I say: as for the verse you brought as proof at the end of your argument, that day precedes night; the verse was not put in this place to inform us which part of the day is the beginning, but to inform us how the Holy One, Blessed be He, takes pity on His people, Israel, in their journeys and encampments for they did not journey nor encamp except during the day. For this reason it stated "day and night" - the cloud settled during the day together with the night which followed. If the cloud lifted on the morrow, during the day, the Israelites would journey along in the light. We could deduce from this that night precedes, except that this is not the place to prove this point. For before this is written:

> "At times the cloud remained from evening to morning, and when the cloud lifted, they journeyed."

Scripture states "...and by night, when the cloud lifted, they journeyed because they did not journey at night and it never happened to them that the cloud remained during the night and the following day such that it would rise at the day's end, at nightfall, because if this were to occur, the Israelites would have had to journey along at night and the Holy One, Blessed be He, took pity on them and did not force this burden on them, and because of this

it said: "by day and by night," and not "by night and by day."

Similarly, the statement of the second scriptural verse was not made to arrange the order of night and day, as to what manner they are counted, but it made known how they testify to the honour of their Creator. It began with the day in which the sun is visible to everyone and likened it to the spoken word to which the ear listens and comprehends As is written: "... day to day utters speech, and nightly..." After this comes night during which the light is hidden and concealed. No one among the people knows where the light is at night, except for men of knowledge. Because of this, it likened it to knowledge which is within the heart,[14] as is written "... night to night reveals knowledge."

Likewise, day preceded in the first scriptural verse and it stated: "Day is Yours; Yours, too, is the night," to teach you that the Holy One, Blessed be He, governs the upper world which is all light and it likened it to day and He,may His name be blessed, governs the lower world which is darkness resembling night, just as when our Rabbis, of blessed memory, said:

> "He knows what is in the darkness and light lodges with Him."[15]

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14. The heart was the seat of wisdom to the medievals.

15. Dan 2:22. This verse is also used in b. Hagigah 12.

This meant: even though it is in the nature of humans that if they stand in the light they cannot see what is in the dark, but if they are in the dark, they can see what there is in the light, and you might infer that nothing can be seen until the light covers, the way of the Holy One, Blessed be He, is not like this, but the light is before Him and He knows what there is in the dark. (The fact) that a thing in the dark does not become bright is to teach you the great difference that exists between His power - may His name be exalted - and the powers of human beings, and none of these verses give proof concerning the order of the day and the night.

As to what they said about the light being more praiseworthy than the darkness, and for this reason it was fit to precede in time, is no proof,rather, there are many things in the world which are laudable and which precede in eminence, yet succeed in time.

You find that man is superior to the rest of the animals, though only in this world, because he has knowledge and understanding and he was given divine laws and commandments by which he either attains merit or is culpable, and such is not the case with the remaining animals. For this he precedes in eminence above them, yet they preceded him in time since they were created on the fifth and the beginning of the sixth days, while man was created after them.

Similarly, all the animals take precedence over the herbs and trees and are superior to them because they possess an animal spirit, while the plants of the ground have neither animality nor a soul and they succeed them in time because the plants of the ground were created on the third day and animals on the fifth and sixth. Thus you can say the day precedes in eminence, yet succeeds in time.

If you say the light was created first and with its creation, day came into existence, we can say to you that we only would count the day from sunrise which was created on the fourth day. Before the creation of the sun, it is well-known that darkness was to be found on the earth for the three days which preceded it, for thus it is written:

> "...they shall serve as lights in the expanse of sky to shine upon the earth." [16]

You learn from this that the light did not appear upon the earth until the fourth day. From this you can deduce that night precedes the day.

Thus we have shown the one who would investigate the beginning of the day, that against each one of the three moments, we have arguments which prevent us from designating it as the beginning of the day. Of the four moments, we only have one left, which is the beginning of the night

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16. Gen 1:15 implying that if they were to give light, before they were created, there must have been darkness.

and it is fitting for us to designate it as the beginning of the day, because if all four possibilities which do not have a fifth are presented to you, and concerning their number, one is possible[17] and you can see that three do not fill the need, you can immediately deduce that the fourth will fulfill your need. Thus in this case, since it is given to us that there is no place to designate as the beginning or start of the day except for one of four moments and we have found out with regard to three of them that they do not fulfill our requirements at all, we do not need a further reason to establish it. However, to avoid conflicts, we say that even though this investigation necessitated us to make the night precede the day, we find reasons from logic, viz: that with which we preceded from the creation of the sun on the fourth day, and because we found most things which precede in eminence, succeed in time, and the day precedes in eminence on account of the light which is found in it and succeeds in time. Since darkness is not an entity, but rather the absence or its disappearance, darkness was potential and afterwards it (day) existed in reality. Thus, this day is first mentioned in potentiality being night.[18]

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17. (SI p.25) heb."ויהיה ענינן מספר להצטרך אל אחד מהם"

18. Day and night correspond to light and the absence of light, before light is mentioned in actuality, it is mentioned in potentiality and this is darkness, therefore night is mentioned first.

Consequently, the night precedes.

These are the proofs from logic, and one who disagrees with us cannot refute them with his counter arguments. As for proofs from the Torah, we find explicit scriptural proof from the order of the progression of the day in that the night precedes in the enumeration, as is written:

"There was evening, then morning, one day."[19]

This verse has no other[20] purpose than to express the order of counting days and the way they were created. Concerning this, scripture states in the portion dealing with Day of Atonement:

"You shall do no work throughout that day."[21]

and this warns us against performing any work for one complete day. At the end it explains to us how "throughout that day" is to be counted and says:

"from evening to evening you shall observe this your sabbath." [22]

Thus we have ascertained from all sources that the beginning of the day is from the setting of the sun, and night precedes day. To this our rabbis of blessed memory, whom we are commanded in every place to listen to them and attend to their words, concurred. This is the order upon which we

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19. Gen. 1: 5

20. (SI p.26) Read אחר for אחד.

21. Lev. 23:28

22. ibid. 32.

base our calculations of the lunations and the equinoxes and solstices, which we will come to discuss, and for whose sake we took trouble over the things which we noted up till now.

COMMENTARY TO THE TENTH GATE

This gate is divided into the following six parts:

a) Division of the day into fractions.

b) Times in rabbinical literature to do with the calendar are measured in terms of the day at the equator.

c) Times are given in terms of the meridian of the eastern extremity.

d) Constellation in which the luminaries were at the day of creation.

e) Position of the sun above the earth on the day of creation, i.e. time of day the luminaries were created.

f) Ruling planets assigned to days and nights of the week and their hours of service.

This is the last section on the day, and it sews up the discussion of the preliminary material so that the process of calendation can now be explained. We are not told yet why the material is important, but basically it is in order to set up certain standards and starting points on which the calculations will be based.

a) Up till now, our base for dividing the day was in hours, further division was based on the fractions of an angle viz: minutes, seconds and thirds etc. bar Hiyya now informs us that for the rabbinic calendar, the day is divided into hours (as before),"parts" (1 hour = 1040 parts), and "moments" (1 part = 76 moments).

b) bar Hiyya notes the problem in dividing a day corresponding to the period from sunrise to sunset into 12 equal parts, since the length of the day increases or

decreases, depending on the season of the year and one's latitude. Consequently each part would be either longer or shorter than 15° of the heaven's apparent rotation. bar Hiyya concludes that since the rabbis did not alter the "lengths" of the hours, they must have based their hours on the day at the equator, where 12 hours always corresponds to a rotation of the celestial sphere through 180°, and therefore one hour corresponds to a rotation of 15°.

c) There is also a question of setting a mean time from which we can interpolate our local time. (A modern example of this is the meridian at Greenwich from which we derive Greenwich Mean Time or GMT) bar Hiyya deduces that when the rabbis give a certain time, it is in terms of the time at the meridian at the earth's eastern extremity. However, it is more likely that their times were given in terms of the meridian at Jerusalem.

d and e) These two pieces of information are required in order to calculate the time of the new moon for a given month in a given year, or the equinox/solstice for any given year. This will be discussed in detail in the following two articles (essays). bar Hiyya shows how the verse in Genesis 1:15 presumes knowledge of (d) and in fact gives (e) which, since this was when the sun was directly above the terrestrial meridian i.e. noon for the people at this longitude, it would be 6 p.m. for the people at the eastern extremity. Now the Bible starts the day in the evening

(=6 p.m.) "proving" bar Hiyya's assertion that the Jewish calendar states its times in terms of the meridian at the eastern extremity.

f) This section closes with a little basic astrology which bar Hiyya concedes is outside his topic of discourse, however, he feels that it was important to include in his treatise because his sources included it. This section has nothing to do with astronomy - at least not with the observable movement of the planets, and is some speculation based on the hours of the days of the week. It still gives us an idea of how some of the days of the week came to be named (see note 23), and also illustrates how difficult it was for medievals to dissociate astrology from astronomy.

THE TENTH GATE

Discusses the hours and fractions of the day and according to the meridian of what place we count the hours of the day for the lunations, solstices and equinoxes: also the different positions of the sun in the celestial sphere which dominate each day and its hours.

According to our rabbis, of blessed memory, and the words of the remaining sages among all the nations, the day is divided into 24 equal parts which are called hours. At night there are 12 hours as the number of the signs of the zodiac or the months of the year. Similarly, there are 12 hours in a day and every hour of them[1] corresponds to a movement of 15° by the sphere with the sun, which is $\frac{1}{24}$th of the degrees in the celestial sphere which comprises of 360 degrees. According to this measurement, all the nations reckon their hours which correspond to 15° every hour. But according to our rabbis of blessed memory, the hour is divided into 1,080 parts[2] which is three times the number of degrees in the celestial sphere. When we come, with God's help, to explain the measurement of the month, it will become clear to you the reason why our rabbis of blessed memory divided the hour into these fractions.

They also divided the parts of an hour into 76 parts which are called moments, because in the calculation of the solstices and equinoxes, we were compelled to divide

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1. the 24 hours in a day.

2. Each 1080th of an hour is called one "part" (heb.פ׳ת)

the "part" into all these moments as will become clear in the proper place - with God's help.

These hours do not correspond to a fixed norm throughout the year except in places lying along the earth's equator. But in the remaining populated regions the hours of the day are never uniform except on two days of the year, as is explained in the first [3] gate of this treatise, and even though day and night are not equal in length, you find that each one is divided into 12 equal parts. Each one of them, whether of the day or of the night, comprise twelve hours throughout the world, except that the degrees which correspond to an hour in one may be greater or less than the degrees in an hour in the second.[4]

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3. cf. p.19.

4. bar Hiyya explains here what occurs if the day (i.e. sunrise to sunset) happens to be longer than the night in a particular place. Given that the day and night are always divided into twelve "hours", then the hours of the day are going to be longer than the hours of the night. bar Hiyya expresses this difference in terms of degrees of arc through which the celestial sphere rotates. 17° per "hour" would occur for a day which was, in terms of 15° hours, 13 hours 36 minutes long. The corresponding night would then equal 24 hrs. - 13 hrs. 36 min. = 10 hrs. 24 mins. long; which corresponds to 13° per hour. A 24 hour day always comprises of a revolution = 360°. Since there are always 12 hours of day and 12 hours of night, then if 12 hours of day take more than 180°, 12 hours of night must take correspondingly less than 180°. Since days and nights are always divided into 12 equal parts respectively, what is added onto an hour of the day will be subtracted from an hour of the night, and vice-versa; but their sum (viz. of one hour of the day + one hour of the night), must always be 30° (360° ÷ 12).

For example, if the degrees of one hour at night equal 17°, then the degrees of an hour in the corresponding day are 13°. Similarly, in the converse situation, as long as the sum of the two hours: one from the night and the other from the day; add up to 30° and the total number of hours in the night and day comprise 360° of the celestial sphere. This is their characteristic throughout the populated [5] region.

From the words of our rabbis, of blessed memory, we learned of the change which occurs between days and nights in the inhabited parts of the earth, when they say that from the autumnal equinox to the vernal equinox, night exceeds the day; from the vernal equinox to the autumnal equinox, day exceeds night: at the autumnal and vernal equinoxes, the two are equal throughout the world. Since we learnt this matter from the words of our rabbis,of blessed memory, and they were experts at it, as they had received the tradition and we have seen that they calculated lunations and equinoxes in hours and parts thereof, whose length was uniform, all the days of the year, and they did not command us to alter the length of the hours whether day or night, neither during the winter days nor during the summer; neither in calculating the equinoxes, nor in calcu-

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5. Populated, because above 66° north, daylight can last longer than 24 hours. cf. gate 3, p.54

lating the lunations, we can clearly deduce, without any doubt whatsoever, that this whole calculation was determined according to the days at the earth's equator.

Once we have clarified this point, we come to consider well and say that certainly, according to the opinions of all the sages, the time of day and night is not seen in the same way in every place, but in a certain place it is day when it is night elsewhere. In one place it may be 3, 4 or 5 hours of day or night, while in a second place it is later than this and in a third place earlier than this. This is the pattern according to which days and nights behave throughout the world, whether at the earth's equator or at any of the lines of latitude of the neighbouring climates. We find that our rabbis, of blessed memory, say that the new moon occured at such and such an hour of the night - and likewise, the equinox falls at a certain hour of the day or night; we have to understand according to which place along the length of the equator [6] they calculated these hours, and upon which they based their calculations, and on knowing this place, we can say from it the time the lunation or equinox will be in the location in which we live.[7] When we come to investigate this matter from every aspect according to our ability, we see that they determine the calculation of the lunations and equinoxes according to those who live at the

6. i.e. according to which line of longitude or meridian.

7. Similar to GMT. If we live 30° east of Greenwich, then 3 am GMT is 5 am our local time.

eastern extremity of the equator. We assure ourselves of this matter, when we see that one of the speculative sages [7a] concurred with us in his opinion and said that this calculation was determined according to the meridian of the edge of the east and it was impossible for it to be according to the meridian of any other place.

The investigation to which I have alluded went according to this order: Given that the celestial sphere makes a rotation around the earth every day from east to west, and carries around with it the luminaries (and as for the luminaries, they independently revolve in the celestial sphere in the opposite direction from that of east to west, and concerning them there are two distinct aspects: one is the movement of the celestial sphere;[8] and the second is the movement of the luminaries), we have to know the following two aspects in connection with the creation of the luminaries:

> Firstly, we have to know in which zodiac sign they were created, so that we can know from which place they started revolving independently in the celestial sphere;
>
> also what moment it was in the year.

After this, we can start to investigate the point at which the celestial sphere began its rotation

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7a. It remains to be found who this "speculative sage" is.

8. Although the sun and moon move independently from west to

with them, because this matter [9] did not occur to them until they were already created and suspended in the celestial sphere.

We found that scripture explained these two matters, each individually. To begin with it said:

> "Let there be luminaries in the vault of heaven to differentiate between day and night." [10]

So as to let you know the need and the benefit which would bring about their creation in the world, and because this need came in two ways, it returned immediately and told you what benefit they bring the world in their independent journey across the celestial sphere and said:

> "they shall serve for signs for the new-moons, the days and the years" [10]

and the new moons and the years can only renew and reoccur,[11] respectively, and be counted off, by way of the revolutions of the luminaries, independently, in the celestial sphere.

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8. (cont) east, they still are "carried" around the world by the celestial sphere. This is what is known as their diurnal motion.

9. Their diurnal revolution in the celestial sphere.

10. Gen. 1:14

11. (SI p.27) מחדשים וחוזרים renew refers to the month which occurs at the new moon. reoccur - better "recycle" refers to the years and the yearly cycles.

Our rabbis, of blessed memory, informed us explicitly in which zodiac sign the luminaries were created, as it is taught:

> "Rabbi Eliezer says the world was created in Tishre; Rabbi Joshua says the world was created Nissan."[12]

and because of this we do not have to extract it from the verse in this place.[13]

Once scripture has shown us the first matter, the evidence being an allusion to the position of the luminaries in the sky; it came to explain the second by stating:

> "And they shall serve as lights in the vault of heaven to shine upon the earth." [14]

and also:

> "God placed them in the vault of heaven to shine upon the earth." [15]

over that part of the world which was called earth. It did not say to rise, or to dawn or to come up over the earth, or to incline, or to set or to go down beneath the earth; all of which features you find concerning the luminaries in the course of the celestial sphere's rotation with them around the earth. Scripture did not mention one of these, but only stated "to shine over the

12. b. RH. 10b f.

13. We now know by looking at the proofs in the Talmud (v. n. 12), that the revolutions started either in Tishre or Nissan, ie. the luminaries were either in Libra or Aries.

14. Gen. 1:15

15. Gen. 1:17

earth", to teach you that at the time of their creation, the luminaries were positioned in the celestial sphere such that the light would be spread out over the whole earth. Such a situation only occurs when the sun is at the centre of the celestial meridian above the earth. This is the point when it is directly overhead the inhabitants of the central region of the earth, and at this time you find that the sun illuminates the whole earth.[16] The people who inhabit the eastern edge see it setting, while the people at the western edge, rising. The remaining areas see it on one of two sides as has been explained in the past gates. The sun shone overhead and its light spread over the whole populated region throughout the earth from east to west and from north to south. From east to west because it was midway across the distance between them; from north to south because it was at the celestial equator: at the entry of Aries according to R. Joshua, or at the entry of Libra, according to R. Eliezer.

Once scripture had shown us this matter, it came and told us what benefit the luminaries provide this world when the celestial sphere rotates with them around the earth.[17]

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16. cf. gate 4,p. 65

17. The movement of the celestial sphere corresponds to what we would call the earth's rotation. Over and above this, the sun and moon were to revolve from west to east among the backdrop of fixed stars - this is what bar Hiyya calls their independent revolution.

It stated:

> "to dominate in the day and in the night and to distinguish between the light and the darkness." [18a]

They distinguish between light and darkness and dominate day and night in the way that the sphere revolves them and not by way that they themselves revolve around it, and from this you learn that at the time of its creation, the sun was set in the celestial sphere at the celestial meridian which is directly above the inhabitants of the centre of the earth - and when it gets to this point, it sets below those who inhabit the edge of the east, which is their nightfall, as is said:

> "It was evening, then morning"[18b]

and we learned that this matter is only according to the meridian of the eastern edge, and it is fitting to begin from this place because from there the celestial sphere begins to rotate and come up over the earth at that point. We saw from this that our rabbis, of blessed memory, computed all their calculations of lunations and equinoxes according to the meridian of this place, viz: the meridian of the eastern edge. Whenever they say the lunation occured before noon or after noon, or the equinox occurs at a certain time of the day or night, they only refer to the eastern edge

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18a. Gen. 1:18

18b. Gen. 1:19 et al.

and to no other place in the world. I will bring a proof from the words of our rabbis of blessed memory concerning this matter when we come to explain the way to determine the new moons and lunations (with God's help).

We have now gained a clear conception of the measurement of the day and night and the explication of their details, the number of their fractions and from what place scripture began to count them.

Know that the luminaries and stars dominate the day and night and serve every hour of the night and the day in the following manner: one star serves at one hour and when the hour is over, the star which was below it in the celestial sphere serves the next hour and thus the matter proceeds; the one serves after the other until seven stars have elapsed in the seventh hour, at which point they return once again in the same way: the star which served the first hour returns to serve the eighth hour and similarly each star in turn returns to serve according to their order in the celestial sphere. They repeat again a third, fourth and even greater number of times until the days comprising the whole week are completed. The way they are ordered in the celestial sphere is the following: the highest one which is the one which begins to serve is Saturn, then Jupiter which is second to serve; the third is Mars; fourth, the sun; fifth, Venus; sixth, Mercury; seventh, Moon. Their mnemonic is according to their order of appearance:

(SaJuMaSuVeMeMo)

Since the luminaries were created on the first hour of the night of the Fourth Day,[19] Saturn, being the first, began to serve the first hour, after it, Jupiter, an hour later, until the week was completed and they repeated their service the same way.

They follow this system, until the world ends in Saturn:

The star Saturn, is in the first hour of the nights of the Fourth Day, and it dominates the nights of the Fourth Day; the second hour, Jupiter serves; the third hour, Mars; fourth, sun; fifth, Venus; sixth, Mercury; seventh, moon; eighth, the service returns as at first to Saturn; ninth, Jupiter; tenth, Mars; eleventh, sun; twelfth, Venus and the hours of Wednesday night are completed with Venus. The Fourth Day begins and the fortune of the server turns from Venus to Mercury. Mercury serves the first hour[20] of the Fourth Day, and governs the Fourth Day; second hour, moon; third, Saturn; fourth, Jupiter; thus the fortune goes as the service of the hours passes from one star to the next on the Fourth Day until it reaches, at the twelfth hour, Mars and the Fourth Day closes with Mars. The nights of the Fifth [21] Day begin and the fortune turns to the sun.

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19. The Fourth Day began at 6 p.m. of the Third Day. This is considered the first hour in Jewish astronomical counting.

20. 6 a.m. of Wednesday.

21. Fifth day of the week, or Thursday.

The sun dominates Fifth Nights and serves the first hour, second, Venus; third, Mercury; and thus they go according to their order in the heavens, star after star until the fortune arrives at the first hour of the Fifth Day, to Jupiter. Jupiter rules this day and serves the first hour. In this manner the fortune turns until the days of the week are completed and the dominion and service returns to the star from which it began.[22]

You find that the order of service and dominion of days and nights goes according to this pattern and corresponds to the mnemonics which you will have at hand. Your mnemonic for days, if you begin with the First Day, is (SuMoMaMeJuVeSat) חלמך צנ"ש [23], while your mnemonic

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22. Saturn

23. If we follow the order given by bar Hiyya, we arrive at the following pattern. The order mentioned is 1. Saturn, 2. Jupiter, 3. Mars, 4. Sun, 5. Venus, 6. Mercury, 7. Moon. Note that 24÷7 = 3 rem. 3. So we count three planets off to the right to get the planet beginning the next day or night. For nights, the order is the following:

4th night: Saturn	6th : Moon (8th)=1st	:Mercury
5th : Sun	7th : Mars	2nd :Jupiter
		3rd :Venus

For days, the order is:

4th : Mercury	6th :Venus	1st : Sun
5th : Jupiter	7th :Saturn	2nd : Moon
		3rd : Mars

Note the correspondence of names in the days of the week! The sun rules the 1st day of the week, Sunday. Moon - Monday; Mars - Tuesday (fr. mardi); Mercury -Wednesday (fr. mercredi); Jupiter - Thursday (fr. jeudi); Venus - Friday (fr. vendredi); Saturn - Saturday.
(SI p. 29) חלמך צנ"ש instead of חלמ"ן צנש.

for the nights is כצן שחל"מ [24] (MeJuVeSaSuMoMa)

The star which serves either night or day at the first hour, is said to dominate that day or night because it serves the world the whole time the sun traverses the earth, from the moment it dawns at the eastern edge, to when it sinks; or from its sinking until it rises, in the following way. The star serves the first hour of the day at the eastern edge, when the sun rises over them. When the first hour of the day has passed from the eastern edge and the second hour has arrived and a different star begins to serve the eastern edge, you find that the sunshines over a different [25] part of the earth and that star which served in the east during the first hour, serves in that place [26] during their first hour. Likewise, the sun dawns over place after place and that star serves the first hour in place after place, until twelve hours are up at the eastern edge when the sun sets while it dawns upon the dwellers of the west and that star serves the first hour for the dwellers of the west, just as it served the first hour in the east. You find that star serves place after place from the eastern end to the western end until thirteen hours are completed. This is the daily pattern. Similarly, the star which dominates the night; its service of the night

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24. (SI p.29) כצן שחג"מ instead of כשנ"צ חלם.

25. for אחד read אחר.

26. where the sun has just come up.

hours is from the setting of the sun in the east until it dawns upon them.

My main intent was not to explain this matter, neither do I think it a necessary part of the treatise. However, since I noticed that the ancients and sages mentioned the service of the stars to the hours during the days and nights, I, myself, was compelled to rely on them and follow them, and I found it necessary to explain the matter as well as I could.

With this, I seal the first article and begin to compose the second article, with the help of the One who has no second.

Completed is the first article with
the help of God, may His Name be glorified
and praised forever and to all eternity.

GLOSSARY

lunar eclipse	לקוח הלבנה
independent motion	מהלך בגופה
becomes extreme	מוסיף על מדתו
characteristic behaviour, norm.	מנהג
carries around, revolves (trans.)	מסיב
encompass	מקיף
apogee	מרחק ארוך
perigee	מרחק קצר
slowness	מתינות
obscured, occulted	נסתר
exceeds, projects,	עודף
increment	עדיפות
perfectly	על בוריו
duration	עמידה
curve, circumference	עקמימות
extremity, edge	פאה
is directed to	פונה
the diameter of its heaven.	קו אורך רקיעה
diameter	קוטר
celestial sphere, heaven	רקיע
deferent	רקיע הסובל
celestial horizon	אופן המפריש
discipline	אמנות
assessment	באמד
contrariwise	בהילופא
altitude	גבה
maximum altitude	גבה הגדול
minimum altitude	גבה הקטן
sun's altitude	גבה השמש
sphere	גלגל
deferent	גלגל הדומה (לגלגל המזלות)
epicycle	גלגל ההקפה
celestial equator	גלגל המישור
celestial sphere	גלגל הרקיע
ecliptic	גלגל רקיע החמה
symbolic (not actual)	דונמא
right angle	זוויח נצב
diversity	חלוף
zenith, meridian	חצי השמים
arithmetician	חשבן
Mercury,(planet).	כוכב החמה
solar eclipse	לקוח החמה

uniform	שוה
uniformity	שווי
phrase,expression	שרש
domain	תחום

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