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Talmudic Metrology VIII: Hours and Time Reckoning in Talmudic and Rabbinic Literature

The measure of time has much evolved through the course of history. In antiquity, the only way to measure time was to examine the movement of the sun (and the stars). Sundials and their primitive form, the gnomon, were instruments that took advantage of the sun's movement by measuring time through the movement of the shadow of the gnomon or the style of the sundial.

This method of measurement explains why, until the eleventh century when they discovered the possibility of directing the style toward the pole star, the ancients measured temporary hours representing the twelfth part of the daylight time.

The introduction of the equinoctial hours in practical life began, slowly, from the thirteenth century onwards, with the progressive building by each wealthy town of a great clock, which was generally adjusted on equinoctial hours for technical reasons.

The sages of the Talmud used probably only the temporary hours, although at the same epoch the inception of the fixed calendar based on the calculation of the Molad (mean conjunction) introduced a uniform time based on the equinoctial hours. However this calculation was probably not widely known.

We show how the understanding of the Talmud was deeply influenced by the evolution of the measure of time. In contrast with the current understanding of the Talmud, some statements (B. Eruvin 56a, B. Shabbat 129b) related to the Horoscope (Mazalot) and the length of the seasons (Tekufot) must also be understood according to the principle of the temporary hours. The current explanation of these passages in uniform time seems to be a re-interpretation according to the new concept of equinoctial hours. We further examine the temporary hours which R. Tam introduced in the second half of the twelfth century according to his own understanding. This new concept had considerable influence on the history of the Halakhah and contributed to a new understanding of many Talmudic texts contrasting with their original significance.

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I. INTRODUCTION

Time reckoning in everyday life in the Talmudic period in Palestine or Babylonia was certainly similar to that in the surrounding society. We already proved that the main elements of Talmudic metrology, such as the units of measure of distance, time, volume, capacity, weight and currency,[1] were deeply influenced by Roman civilization, the dominant culture of the period and a powerful force in Palestine, which was under Roman rule during Talmudic times.

Thus, also regarding the hour and time reckoning, the influence of the surrounding civilizations was certainly important. We will be able to complete our lack of information about Jewish time reckoning with the general information available about the Roman, Grecian and ancient civilizations. The ancient civilizations measured time with the sundial, which allowed them to know the time in temporary hours, i.e. twelfth parts of the daylight limited by sunrise and sunset. Herodotus reported that the Greeks had adopted sundials and the 12 divisions of the day from the Babylonians. As far as the night was concerned, for civil use it had no division at all. For military purposes, it was broken down into three or four segments, the length of which varied with the seasons. The day – daylight from sunrise to sunset – was divided into twelve segments, called hours, of equal length. In contrast, the Babylonians divided both periods, daylight and nighttime, into twelve hours. The Talmudic conception of time reckoning was similar to the Greek system: the night – from sunset to sunrise – was divided into three or four equal segments, and the day – daylight from sunrise to sunset – was divided into twelve equal hours. The duration of these hours varied with the length of daylight, depending on the season and the latitude of the specific location. The end of the sixth hour was always designated the midday point, when the sun is at its culmination. Only twice a year, at the equinox, were the hours of the day and the night equal in length. These hours were called temporal, temporary or seasonal hours.

The drawback of this system was the variation of the length of the hour during the year. However, in Palestine the drawbacks of this inequality were certainly limited, as the ratio of the longest to the shortest daylight hours was about 1.42 : 1, less than in Athens and Rome where the ratios of the longest to the

1 See the series of papers published in B.D.D. from n° 19 onwards: J. Jean Ajdler: *Talmudic Metrology*.

shortest daylight hours are 1.55 : 1 and 1.73 : 1.[2] We have various pieces evidence attesting to the use of sundials in Palestinian civil life at the time of the Mishnah and the Talmud:

1. Archeological discoveries. Benish[3] has described a sundial discovered in archeological excavations near the Temple Mount.
2. Quotations in the Mishnah.[4]

The sundials were always graduated according to the system of temporary hours. The hours generally[5] mentioned in the Talmud were certainly hours as indicated on the sundials. It is only in the Arab period, in about the eleventh century that the Arab astronomers made a decisive improvement in the gnomonic when they proposed to use a style parallel to the earth's rotational axis – oriented towards the pole star – instead of the vertical or horizontal styles used until then. With this system it was possible to use equinoctial hours year round. Furthermore, it was now the totality of the gnomon's shadow that indicated the hour and not only the shadow of its edge. In other words, in this new system, even if the length of the shadow at a given hour changes during the year, the direction of the shadow stays the same throughout the year.

This decisive improvement had no immediate consequence. Despite the evident advantages of the equinoctial hours, people were so accustomed to the temporary hours that this new system made no practical difference; people went on using temporary hours.

The temporary hours remained in use until late in the fifteenth century, and the noted astronomer Regiomontanus[6] still published his almanacs announcing the astronomical phenomena in temporary hours. Similarly, weight-driven clocks had existed already for quite some time when the temporary hours finally disappeared. Still in the fifteenth century, each evening at sunset, one would

2 Even in Rome, where the ratio of the longest to the shortest daylight hours is rather significant, civil life was organized around the concept of the temporary hours. Waking, bedtime and meals were at fixed temporary hours. See Carcopino Jérôme, La vie quotidienne à Rome à l'apogée de l'empire, pp. 171-181 and 304-307; Hachette 1939 and 1972. See also Dupont, Florence, La vie quotidienne du citoyen romain sous la république, 509-27 av. J-C ; Hachette 1989. Both books were translated into English.

3 *Ha-Zemanim ba-halakha*, P. Benish Benei Berak 1996, p. 81.

4 Mishna Kelim XII, 5 and Mishna Eduyot III, 8.

5 With some exceptions when it deals with astronomy or astrology; see further.

6 Johannes Müller (Königsberg 1436 – Rome 1472).

change the pendulum bob or the balance wheel of these clocks in order to divide the nighttime, i.e. the span of time between sunset and sunrise, into twelve equal parts, and similarly one would again change this component each morning, in order to divide the daytime into twelve equal parts corresponding to the daytime hours.

In fact, it is the installation of great clocks with bells in affluent European cities, with the aim of regulating and standardizing the laborers' working day, which was the route cause of the generalization of the use of the equinoctial hours. It was indeed much more difficult to regulate these clocks according to the temporary hours' system, and therefore these clocks were regulated on the basis of average hours called the equinoctial hours. These clocks and their bells, which were heard in the city, literally killed the temporary hours.[7] It is only then that equatorial sundials spread. The introduction of the equinoctial hours in both general and rabbinic literature was thus something progressive and not clear-cut; it extended throughout the thirteenth, fourteenth and even fifteenth centuries, depending on the local circumstances.[8]

In the system of temporary hours, the hours were counted as night hours from sunset and day hours from sunrise. There were 12 night hours and twelve day hours.

We have an interesting piece of evidence from approximately the eighth century, found in the Baraïta de Shemuel about the use of hours that appear to be temporary hours. The Baraïta writes indeed[9] that at the solstice of Tamuz the day hour lasts 18 [10]חיל or 72 m and the night hour lasts 12 חיל or 48m. At the solstice of Tevet the situation is inverted. At the equinox of Nisan and Tishri the day hours and night hours are equal. The hours mentioned by the Baraïta are thus temporary hours counted from geometrical sunrise until geometrical sunset.[11]

7 L'horlogerie a-t'elle tué les heures inégales ? E. Poulle, Bibliothèque de l'Ecole des Chartes, t. 157, Janvier-Juin 1999, pp.137-156.

8 It may be interesting to note that also in other civilizations, despite the drawbacks in our opinion, the system of temporary hours subsisted a long time after the introduction of the clock; in Japan the temporary hours were still used under the Meiji dynasty in 1873.

9 Chapter 3.

10 חיל represents 1° of the equator used for counting the hour angle i.e. 4 minutes. Thus one hour = 15 חיל.

11 If we consider in Israel Fi=32° and ε=23.5° then Cos H = – tang Fi*tangε gives at the summer solstice H=105.77° = 7.05h and 1 temporary hour = 70.5m and at the winter solstice H=74.23° = 4.95h and 1 temporary hour = 49.5m. If we consider Fi= 35° in

After the introduction of the system of equinoctial hours, different systems of counting these hours were introduced in the different European countries:

1. Counting 24 hours beginning from one half-hour after sunset: the "Italian clock". A half-hour after sunset corresponds to about the end of the civil twilight. At this moment, working outdoors without artificial lighting becomes impossible. This system of counting the hours allowed for the easy calculation of the remaining working time. A variant form of the "Italian clock" began at sunset. The clock had to be set once a day at sunset, or more commonly a half hour later.[12]
2. The "Great Clock" system, also called the "Nuremberg Clock" continued to consider day hours and night hours following the tables of the length of the days and night. It used equinoctial hours but it followed the spirit of the old temporary hours system. The night hours began at sunset and the day hours began at sunrise but the number of night and day hours was variable and must be pre-calculated by tables. The clock must be set twice a day, at sunset and sunrise.[13]
3. The "Small Clock" system is our modern system. The system worked on the basis of the dual sequence of 12 hours, which we still use today. 12 hours symmetric with regard to midnight were the night hours and 12 hours symmetric with regard to noon were the day hours. It had to be set only once a day at true noon, without using any table. This system could also be used from 0h to 24h, beginning from noon.[14]
4. The Jewish Me'abrim had already much earlier introduced a system of counting the meantime for the calculation of the Molad. In this system, as in the system of the "Small Clock" the 12 hours symmetric with regard to noon are the day hours and the 12 hours symmetric with regard to midnight are the night hours. Today the system works on the basis of 24 h beginning

Babylonia, we find in summer H = 107.73° and a temporary hour of 71.82m and in winter H = 72.27° and a temporary hour of 48.18 m. The Baraïta thus gives correct indications for Babylonia.

12 This system was used mainly by Italian, Bohemian and Polish rabbis: R. Samuel Aboav (Devar Shemuel), R. Samson Morpurgo (Shemesh Tsedaka) and R. Joel Sirkes (Bayit Hadash).

13 This system was used mainly by the Tossafists and German Rabbis. See B. Eruvin 56a Tossafot אין.

14 This system corresponds to our modern system of counting time. R. Jacob Emden refers to this system in his writings.

at the beginning of the night at 6 p.m. At the time of the Geonim, they used rather a dual sequence of 12 h, 12 night hours beginning at 6 p.m. and 12 day hours beginning at 6 a.m.

The proper interpretation of many rabbinical writings requires understanding to which system the author referred.

II. THE HOURS IN THE TALMUD

1. Religious Hours Are Temporary Hours

They are the temporary hours read on a sundial; they coincide with the equinoctial hours twice a year, on the days of the equinox. The religious hours connected to the prayers in B. Berakhot, to the time schedule of the eve of Pesah in B. Pesahim, and to the fixing of a woman's cycle in Niddah IX, 9 are temporary hours. In the ancient world, civil time was always measured in temporary hours.[15] Water clocks were exceptionally used in astronomical scientific research; there is however no mention of such devices in the Talmud.

2. Alleged Uniform Time in the Talmud

We find however a few cases where the Talmud deals with subjects connected to spans of time covering days and nights or parts of them. They are generally understood today as counted in uniform time,[16] whether equinoctial hours counted from 0h till 24h from the origin at 6 p.m. or two dual sequences of 12 equinoctial hours: the evening hours counted from 6 p.m. and the day hours counted from

15 In B. Berakhot 3b it speaks about David awaking at midnight, two guards before the other kings, each guard of the three night guards having a length of four hours. The Talmud explains this statement as follows: שית דליליא ותרתי דיממא, הוו להו שתי משמרות. Only if we consider that the Talmud speaks about the days of the equinox, the day and night temporary hours are equal and the six night hours and the two day hours add together and represent two guards of 8 hours. On other days the six hours have a different length than the two hours.

16 This is today the standard explanation. See B. Eruvin 56a glosses of R. Samuel Strashun. See also Lehem Shamaïm, R. Jacob Emden on Mishna Berakhot I: 2 , Altona 1768. For the calculation of the Tekufah, according to this system, see Tor, O.H. 428 and Shulhan Arukh O.H.428: Peri Hadash (Hezekia Da Silva).

6 a.m. This is the case for the hours mentioned about Tekufot[17] and Mazalot.[18] However, this exegesis does not hold out against a thorough analysis. The principle of the planetary hours is not specifically Jewish. On the contrary, it belonged to the surrounding society and in fact was completely in objection with Jewish principles. However it infiltrated into Jewish society and asserted itself even among some of the greatest Amoraim.[19] We know however, from external

17 Samuel (end of the second century – 247) had introduced the tropical year fixed by Sosigenes (Caesar's astronomer) of 365.25 days leading to four seasons of an average length of 91 days 7.5 hours. Of course these hours can belong to the day, the night or partially to both and they must necessarily be equinoctial hours allowing measuring uniform times. The subject is met in B. Eruvin 56a where the rules about the time of occurrence of the four mean tekufot (equinox and solstices) is enunciated. It can only be understood when expressed in uniform time. For this purpose one considers a theoretical day at the equator where sunrise is always at 6 a.m. and sunset at 6 p.m. or in a more abstract form, a day in which one considers that the six hours, before and after midnight, are the night hours and the six hours, before and after noon, are the day hours. This abstracted day is also the basis of the Jewish calendar and its Molad's reckoning.

18 The Talmud considers a form of astrology according which the seven planets in rotation, an hour each, influence the world. These seven planets are: the Sun, the Moon, Mars, Mercury, Jupiter, Venus and Saturn. The question is approached in B. Sabbath 129b and 156a, B. Berakhot 59b and B. Eruvin 56a. The influential planets at the beginning of the standard day nights, at 6 p.m., are Saturn, the Sun, the Moon, Mars, Mercury, Jupiter and Venus.

The influential planets at the beginning of the standard daylights, at 6 a.m. are, beginning with Sunday: the Sun, the Moon, Mars, Mercury, Jupiter, Venus and Saturn. This coincidence with the name of the days of the week seems to indicate that this astrological belief belonged to the surrounding societies and was at the origin of the names of the weekdays in Latin society and later in English, French and probably other languages. Similarly, in B. Berakhot 3b, when Rashi mentions at the bottom of the page a quotation from B. Gittin 31b and Bava Batra 25a about the wind blowing four times a day, each time in another direction, he writes that these winds blow, in rotation, all the six hours. Necessarily we speak of an abstracted day whose 12 hours symmetric around noon are the day hours and the 12 hours symmetric around midnight are the night hours. This system of counting the equinoctial hours would become later, with the generalization of the urban clocks, the system known under the name "Small Clock". Rashi, by contrast with some Tossafists, like R. Isaac of Dampierre, was accustomed to this way of counting the hours of an abstracted day working like an equatorial day. R. Jacob ben Shimshon, his secretary, was a noted specialist of the calendar. Further, he mentions in B. Eruvin 56a bottom, that he learned the subject in "the book Sefer Tahkemoni of the physician Shabtai Donolo of blessed memory".

19 Astrology seems to be an accepted fact in the Talmud. Even those Tanaïm and Amoraïm who objected to this belief, accepted in fact that the power of the stars acts on the ordinary mortals but it does not extend to the people of Israel (see the opinions of Rabbi Johanan B. Sabbath 156a). However Rabbi Hanina bar Hama held the opposite opinion. Later in

sources, that the planetary hours[20] were evaluated in temporary hours.[21]

Table 1: Planetary Hours of the Days of the Week

Hour	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	Sun	Moon	Mars	Mercury	Jupiter	Venus	Saturn
2	Venus	Saturn	Sun	Moon	Mars	Mercury	Jupiter
3	Mercury	Jupiter	Venus	Saturn	Sun	Moon	Mars
4	Moon	Mars	Mercury	Jupiter	Venus	Saturn	Sun
5	Saturn	Sun	Moon	Mars	Mercury	Jupiter	Venus
6	Jupiter	Venus	Saturn	Sun	Moon	Mars	Mercury
7	Mars	Mercury	Jupiter	Venus	Saturn	Sun	Moon
8	Sun	Moon	Mars	Mercury	Jupiter	Venus	Saturn
9	Venus	Saturn	Sun	Moon	Mars	Mercury	Jupiter
10	Mercury	Jupiter	Venus	Saturn	Sun	Moon	Mars
11	Moon	Mars	Mercury	Jupiter	Venus	Saturn	Sun
12	Saturn	Sun	Moon	Mars	Mercury	Jupiter	Venus

the rabbinical literature, we also find divergent positions. Maimonides had a firm and rigorous position. He rejected any form of astrology as a form of heresy: see Hilkhot Avodat Kokhavim XI; 8, 9 and 16. See also his epistle to the people of Montpellier, Igerot ha-Rambam, Isaac Sheilat, Vol 2, pp. 474-490; especially p. 488 where he concedes that some Tanaïm erred and accepted a relation between the moment of someone's birth and his character because of the power of the star ruling at his birth.

20 The planetary hours used in the Talmud corresponded to the ancient system in which one of the seven traditional planets, sun and moon included, is given sovereignty over each day and also various parts of the day. Each planetary day begins at sunrise and ends at the next day's sunrise. The day is divided into two parts, the day (between sunrise and sunset) and the night (between sunset and sunrise).Each part of the day is divided into 12 equal parts. The first planetary hour of the day is always the same as the planetary day: on Sunday, the sun; on Monday, the moon; on Tuesday Mars; on Wednesday, Mercury; on Thursday, Jupiter; on Friday, Venus and on Saturday, Saturn.

21 See Planetary hours in Wikipedia. See also Rohr, R.R.J. Sundials, History, Theory and Practice; Dover 1996, pp. 95-97.

Table 2: Planetary Hours of the Nights of the Week

Hour	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	Jupiter	Venus	Saturn	Sun	Moon	Mars	Mercury
2	Mars	Mercury	Jupiter	Venus	Saturn	Sun	Moon
3	Sun	Moon	Mars	Mercury	Jupiter	Venus	Saturn
4	Venus	Saturn	Sun	Moon	Mars	Mercury	Jupiter
5	Mercury	Jupiter	Venus	Saturn	Sun	Moon	Mars
6	Moon	Mars	Mercury	Jupiter	Venus	Saturn	Sun
7	Saturn	Sun	Moon	Mars	Mercury	Jupiter	Venus
8	Jupiter	Venus	Saturn	Sun	Moon	Mars	Mercury
9	Mars	Mercury	Jupiter	Venus	Saturn	Sun	Moon
10	Sun	Moon	Mars	Mercury	Jupiter	Venus	Saturn
11	Venus	Saturn	Sun	Moon	Mars	Mercury	Jupiter
12	Mercury	Jupiter	Venus	Saturn	Sun	Moon	Mars

Table 3: Perpetual Table of the Tekufot in the Julian Calendar

Remainder of the division by 4 of the Jewish date	Tekufah of Tishri	Tekufah of Tevet	Tekufah of Nissan	Tekufah of Tamuz
	September	December	March	June
1	24 at 3 a.m.	24 at 10;30 a.m.	25 at 6 p.m.	25 at 1;30 a.m.
2	24 at 9 a.m.	24 at 4;30 p.m.	25 at 12 p.m.	25 at 7;30 a.m.
3	24 at 3 p.m.	24 at 10;30 p.m.	26 at 6 a.m.	25 at 1;30 p.m.
4	24 at 9 p.m.	24 at 4;30 a.m.	25 at noon	24 at 7;30 p.m.

Table 4: Length of the Tekufot

Remainder of the division by 4 of the Jewish date	Tekufah of Tishri	Tekufah of Tevet	Tekufah of Nissan	Tekufah of Tamuz	Total
	Excess with regard to 91 days.	Excess with regard to 91 days.	Excess with regard to 91 days.	Excess with regard to 91 days.	Excess with regard to 364 days.
1	9h – 1.5sh	1.5sh + 6h	6h + 1.5sh	–1.5sh+9h	30h
2	3h + 4.5sh	1.5sh + 6lh	6sh + 1.5lh	4.5lh + 3h	6h+12lh+12sh = 30h
3	9h – 1.5lh	1.5lh + 6h	6h + 1.5lh	–1.5lh+ 9h	30h
4	3h + 4.5lh	1.5lh + 6sh	6lh + 1.5sh	4.5sh + 3h	6h+12sh+12lh = 30h

We represent the equinoctial hours or mean hours by h, the temporary hours of the days of Tamuz and the nights of Tevet by lh (longest hour) and the temporary hours of the nights of Tamuz and the days of Tevet by sh (shortest hours). Of course 1lh + 1sh = 2h. We can conclude that the time of the Tekufot could perfectly be understood in temporary hours. The total length of the four Tekufot of each year amounts 365, 25 mean days.

Moreover, how could people have calculated the ascending planet reigning at their birth if the required time must be expressed in equinoctial hours? Similarly the length and the moment of the Tekufot in the Talmud are calculated in temporary hours. Indeed the Tekufot and the Mazalot must be expressed in the same time; it is the only way to allow calculating simply the planetary hour of the Tekufah.[22] Of course this way of counting the Tekufot in the Talmud seems odd and different than the classical accepted understanding of the Talmud; furthermore the Tekufot of Tevet and Tamuz are slightly displaced, but no systematic drift follows as it appears in tables 3 and 4.[23]

22 See B.Eruvin 56a bottom, where the connection between the moment of the Tekufah and the planetary hour is considered. Besides, Tekufot and Mazalot are generally mentioned together and should work according to the same time system.

23 If we accept that the Tekufot and Mazalot were calculated in the Talmud according to the temporary hours, it becomes likely that the Moladot were also calculated at the beginning in temporary hours. This did not introduce a systematic drift because 235 lunar months are practically equal to 19 solar years and the little excess of 1h 485p at the end of the 235 lunar months corresponds to temporary hours of Tishri equal to equinoctial hours.

3. Astronomical Dawn and Dusk in the Talmud[24]

Table 5: Different Possibilities for Day Division

Case:	A	B	C	D	E	F
From dawn until sunrise, in miles	5	5	4	4	3	3.75
From sunrise until sunset, in miles	40	30	40	32	30	30
From sunset until end of astronomical twilight, in miles	5	5	4	4	3	3.75
From begin of astronomical dawn until end of astronomical twilight, in miles	50	40	48	40	36	37.5
Complete day time + prolongations before the beginning of dawn and after the end of twilight, in miles	--	--	--	--	40	40
Fraction $\frac{twilight}{day\ (short)}$	$\frac{1}{8}$	$\frac{1}{6}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{10}$	$\frac{1}{8}$
Fraction $\frac{twilight}{day\ (long)}$	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{12}$	$\frac{1}{10}$	$\frac{1}{12}$	$\frac{1}{10}$
Duration of a mile, in minutes	18	24	18	22.5	24	24
Duration of astronomical twilight, in minutes	90	120	72	90	72	90

Day (short) = day between sunrise and sunset.
Day (long) = day between the beginning of astronomical dawn and the end of astronomical twilight.

In B. Pesahim 93b – 94a the Talmud discusses the ratio between the astronomical dawn and dusk to the length of the day. The discussion is connected to the Paschal sacrifice of the afternoon of the eve of Passover. It discusses the distance above which one is dispensed to walk to Jerusalem to perform this sacrifice and one is postponed to Pesah Sheni on the following month. In principle, in the Talmud, the astronomical day begins at sunrise and ends at sunset while the religious day begins at dawn and ends at the end of twilight. The hours of the day are temporary hours counted from sunrise until sunset.

24 The present presentation is a short summary of a long analysis published in the paper: "Talmudic Metrology II: The Mile as a Measure of Time": Ajdler, J. J. published in BDD 20. At first glance, this Talmudic discussion is not connected to the notion of hour. However it will appear that this Talmudic discussion is directly connected to the notion of long temporary hours, which plays such an important role in rabbinic literature. Furthermore it discusses the span of time corresponding to a mile; it has also a considerable importance in Halakhah.

It is generally accepted that the day and night have the same length at the equinox. However, in one quotation of the Jerusalem Talmud,[25] according to the current reading, Rabbi Hanina, the colleague of the sages, considered erroneously that the equality at the equinox of the day and night relates to the extended day between dawn and dusk and the shortened night between dusk and dawn.

The discussion turned also upon the distance covered by an average walker leaving Modiin for Jerusalem on the eve of Passover to participate in the slaughtering of the Paschal lamb. The Talmud departs from the principle that a man covers 40 miles in a day. There are actually two parameters, which enter into consideration of the problem:

- The ratio of the twilight and the dawn to the length of the day.
- The celerity of the walker.

A first opinion examined in the Talmud was ascribed by Rava and Rabba bar Bar Hanna to Rabbi Johanan and corresponds to the column B of table 5 above. This solution leads to a ratio of dawn to the length of the day of 1/6 and it was rejected by the Talmud because it contradicts an independent statement of Rabbi Judah according which this ratio is 1/10. As we see in our table there are only two possible ways to satisfy this condition, to take either column C or column E.[26]

A second solution is given by column C; it is the opinion of Rabbi Judah.

A third solution is given by column E; it seems to be the opinion of Rabbi Johanan but the Talmud did not elaborate on it.[27]

Practically, the Talmud accepted two opinions: whether a fast walker who covers 20 miles during the 6-hours' time of the walk giving a day of 4 + 40 + 4 = 48 miles between daybreak and the end of twilight (column C) or an average walker covering 15 miles during the walk of 6 hours giving a day of 3 + 30 + 3 = 36 miles between daybreak and the end of twilight (column E). In this last case the walker must still walk two miles before daybreak and two miles after the end of

25 J. Berakhot I, 1; p. 3b in the Vilna edition. Because of this difficulty R. Abraham Pimentel proposed to change the reading.

26 As far as we consider that the ratio 1/10 is the ratio of the length of dawn or dusk to the length of the day considered actually in the same way as the ratio 1/6, i.e. the restricted day counted from sunrise until sunset.

27 The Talmud mentions that Ulla and Rabba bar Bar Hanna misunderstood Rabbi Johanan. The latter's position was not rejected but the Talmud did not elaborate on it. Most of the commentators considered, as Rashi, that Rabbi Johanan changed his mind and completely backed Rabbi Judah.

twilight in order to complete the 40 miles.[28] This solution seems more farfetched but it was accepted by the Talmud. The existence of these two possibilities, a fast walker and an average walker seems surprising. Apparently, at the end of the third century Jews were still not allowed to visit Jerusalem as a result of Hadrian's order and therefore the Talmud no longer knew the true distance between Modiin and Jerusalem. By contrast Rabbi Akiva mentioned in the Mishna as the author of the statement about the role of Modiin, and Rabbi Judah, his pupil, were certainly aware of the true distance between Modiin and Jerusalem. Apparently the solution of the Talmud corresponding to the true interpretation of the Mishna was the solution of Rabbi Judah taking into account the distance of 20 miles equal to about 29.6 km[29] between Modiin and Jerusalem.

4. The Religious Day and the Civil Day in the Talmud

While the civil day begins at sunrise and ends at sunset, the religious day begins at daybreak and ends at the appearance of the first night stars. This is taught by the Talmud B. Berakhot 2a and Megilah 20b from a verse in Ezra showing that the working day begins at daybreak and ends with the appearance of the first night stars, when it becomes impossible to read a text outside. This dissymmetry results probably from the fact that in the morning the eye, accustomed to the obscurity, has a greater acuteness than in the evening. However it appears that the period of dawn and dusk is an extension of the actual day but it has not exactly the same status. The religious obligations of the day must be performed a priori after sunset, but a posteriori they were validly performed if they were accomplished after daybreak. Similarly the halakhic day lasts until the appearance of the first night stars which in fact appear at about the end of the civil twilight. The existence of the quotations, B. Pesahim 2a: והא קיימא לן דעד צאת הכוכבים ממא הוא and in B. Megilah 20b : הא קיימא לן דעד צאת הכוכבים לאו לילה הוא, would prove that the span of time of twilight is not night but it is not really day; it seems to be an area of doubt corresponding to Bein ha-Shemashot. The performance of the religious obligations during this period would be still valid a posteriori, but vitiated by a part of doubt.

28 Nearly all the Rishonim championed the solution presented by column D: 4 + 32 +4 = 40 miles. But in this solution 4 miles is the tenth part of the total walk of the extended day! See above note 26.

29 The Talmudic mile is equal to the Roman mile and it measures 1481.5 m. See "Talmudic Metrology I: The Mile as a Unit of Length". J. J. Ajdler. BDD n° 19. The velocity of Rabbi Judah's walker is thus 4.94 km/h and that of Rabbi Johanan's walker is 3.70 km/h.

5. The Twilight of 4 Miles After Sunset and the Bein ha-Shemashot[30] of ¾ Miles

The four miles of the dawn before sunrise define clearly the daybreak, when the first rays of the sun become visible. By symmetry the four miles of the twilight define the moment when the last ray coming from the sun is still visible at the horizon. At this moment the darkness reaches its maximum and all the stars are now visible, or, in other words, no additional stars will become visible and the darkness will increase no further.

In B. Shabbat 34b-35a it defines an area of incertitude between day and night whose length is subject to discussion, but the length adopted by the halakhah is 0.75 miles. This span of time follows sunset immediately or slightly later and its end coincides more or less with the first appearance of the first three medium-sized night stars.

It is important to note that the four miles of twilight are counted, on the day of the equinox, from 6 p.m. true time, the moment when on this day the altitude of the sun is 0°. In other words it is the moment when the center of the sun is at the horizon without taking into account the refraction and the semi-diameter of the sun. This moment is in fact the end of the twelve hours of daylight between sunrise and sunset and it is the beginning of the four miles of the twilight. By contrast those who consider that the BHS[31] begins immediately after sunset refer to the apparent sunset, which, today, is called the astronomical (apparent) sunset, when the upper limb of the sun disappears at the horizon. This corresponds to the moment when the depression of the sun is 0.85°, taking into account the semi-diameter of 16' of the sun and the refraction at the horizon of 34', thus a depression of 50'.

III. THE POSITION OF RASHI AND TOSSAFOT

It must be noted that all the Rishonim, Rabbi Hananel, Rashi and Tossafot all had the reading about the solution of Ulla of 1/6,[32] thus the ratio of the length of twilight to the length of the actual restricted day i.e. the span of time of 12 hours on the day of the equinox, between geometric sunrise and sunset.[33] Nevertheless

30 In short BHS.
31 Bein ha-shemashot.
32 B. Pesahim 94a.
33 Considering the center of the sun without taking into account the effect of refraction.

the Rabbis did not pay any special attention to this point and they all understood the position of Rabbi Judah according to column D, necessarily changing the signification of the ratio of 1/10, which becomes now the ratio of the length of twilight to the length of the extended day.

Apparently the only possible explanation must be that they were persuaded that the distance between Modiin and Jerusalem was 15 miles or maximum 16 miles[34] and they could not imagine that the Talmud could accept such important differences of celerity as 3.33 miles per hour in column C versus 2.5 miles per hour in column E. Furthermore at the rate of 3.33 miles per hour the distance Modiin – Jerusalem of 15 miles could be covered in 4.5 hours and this would raise the question why this distance must be considered as a long distance if the available time is 6 hours. Furthermore as soon as they considered that the dictum that a man walks 40 miles in a day applies itself to the extended religious day, they had no reason to consider a solution leading to a total of 48 or even 50 miles a day.

1. Rashi

Rashi was principally a literal commentator and it is difficult to create a general synthesis of his interpretations in different treatises. It is even possible to find the same Talmudic statement with different explanations in different places. Rashi, like R. Hananel, considered that the solution of Rabbi Judah is given by the column D, giving a day of 4 + 32 + 4 = 40 miles in an extended day and 32 miles in the restricted day of 12 hours, and 1 mile represents thus 22.5 minutes. Apparently there is no reason to believe that Rashi considered other temporary hours than the short temporary hours given by a sundial and coinciding with the equinoctial hours on the day of the equinox. However some of his statements[35] prove clearly that his religious day began at daybreak and ended at the appearance of the stars.[36]

2. Tossafot (R. Tam)[37]

The Tossafot at our disposal in the printed editions of the Talmud, according to

34 Taking into account the distance of Jerusalem to the Temple Mount.

35 B. Berakhot 59b: תחילת הימים הוא בעלות השחר. B. Berakhot 26a: תפילת מנחה עד הערב, עד חשכה. B. Avodah Zarah 25a: היה אותו יום מעלות השחר עד יציאת הכוכבים.

36 In all likelihood, the first night stars.

37 R. Jacob (Tam) ben Meir of Ramerupt (~ 1100 - ~ 1171)

the choice made in its time by the editors of the first edition of the Talmud by Bomberg,[38] are not a homogeneous composition. The Tossafot of the different treatises of the Talmud are not the work of one single author or one unique school. Therefore it is not easy to sort out the opinions and make a synthesis of them.

R. Tam introduced some revolutionary concepts in our field:[39]

- R. Tam placed Bein ha-Shemashot, the span of time of doubt, according to Rabbi Judah, between day and night, at the end of the twilight of 4 miles and enacted that the 3.25 miles following sunset are still day while the last 0.75 miles have the status of doubt of BHS.[40]
- The religious day defined in B. Berakhot 2a between daybreak and the night stars is now extended between daybreak and the end of the astronomical twilight, 4 miles before sunrise and 4 miles after sunset.[41] This day is

38 Venice, 1520-1523.

39 R. Zalman Koren published a paper in 2003: Al shitat ba'al Terumat ha-Deshen, Yad Yshak, Kerem be-Yavneh, 5763 pp. 9-76, in which he tried to make a synthesis between contradictory quotations of Tossafot: (a) Tossafot counts the temporary hours from daybreak until astronomical twilight (Pesahim 11b Tossefot דב"ה אחד, Sanhedrin 41a Tossefot בד"ה אחד, Berakhot 3a Tossefot בד"ה למאן) and (b) The temporary hours coincide with the equinoctial hours at the equinox (B. Berakhot 3b: see the statement שית דליליא ותרתי דיממא הוו להו שתי משמרות and Eruvin 56a Tossefot ואין בין תקופה). R. Koren ascribed to Tossafot the erroneous notion that on the day of the equinox, the span of time between daybreak and the end of dusk is equal to the span of time between the end of dusk and dawn. After correction of this material error, the temporary hours of Tossafot would then coincide with those of the surrounding society and be equal to the equinoctial hours on the day of the equinox and the mile would correspond to 18 equinoctial minutes. The whole theory of Tossafot would then rest on a blunder ascribed to Tossafot. I think that this theory of R. Koren must be vigorously rejected because:
a. It fails to distinguish the two contradictory opinions of R. Tam and R. Isaac the elder, which is proved by sufficient sources. It mixes up elements of these two contradictory opinions.
b. It seems difficult to ascribe to Tossafot such a blunder, which any Christian scholar in contact with the French or Provencal rabbis could have elucidated with an armillary sphere or with an astrolabe.
c. Furthermore even on the day of the equinox, the temporary hour of R. Tam is 1.25 or 1.2 equinoctial hours and cannot coincide with the hour read on the sundial.
d. It seems more advisable to consider that R. Tam and his followers knew that at the equinox the night = the day = 12 equinoctial hours. However the Jewish day was still greater than the night because it contains dawn and dusk.

40 See B. Sabbath 35a Tossafot בד"ה תרי and B. Pesahim 94a Tossafot בד"ה רבי.

41 B. Pesahim 11b Tossafot, B. Sanhedrin 41b Tossafot בד"ה אחד and B. Berakhot 3a Tossafot בד"ה למאן.

symmetrical with regard to noon.

- There is certain confusion between the different quotations whether the dawn and dusk last 4 or 5 miles. The length of 5 miles is problematic.
- R. Tam invented, in a purely intellectual and speculative manner, a new method of counting the temporary hours. While the temporary hours were physically readable on a sundial, the temporary hours of R. Tam were the twelve equal segments of a theoretical Jewish extended day beginning at daybreak and ending at the end of the astronomical twilight. The length of dawn and dusk, according to R. Tam, were probably a constant fraction of 1/8 of the length of the day.[42]

3. Tossafot (R. Isaac the Elder of Dampierre, Ri in Abbreviation)[43]

- R. Isaac the Elder seems to share the opinion mentioned in Tossafot that the minor fasts can be ended at sunset,[44] probably because this moment is the beginning of BHS.
- He ruled that BHS immediately follows sunset and ends an hour before the end of the astronomical twilight.[45] On Sabbath he would then begin Sabbath at sunset but he would wait, at the end of Sabbath, until the end of the astronomical twilight.[46]
- He ruled explicitly that there is still light in the sky at the appearance of the first medium-sized night stars.[47] Therefore in other fields than the end

42 According to column D. However in some cases he seems to use column B which is problematic because it was rejected. Column A would be a better solution, but we have cases where the text follows column B, which is problematic.

43 R. Isaac ben Samuel of Dampierre (~ 1115 – ~ 1185) was the nephew, pupil and follower of R. Tam. His main pupils were R. Samson ben Avraham of Sens and R. Judah Sir Leon, head of the Academy of Paris.

44 See B. Menahot 20b Tossafot בד"ה נפסל and B. Avoda Zara 34a Tossafot בד"ה מתענין. See also Benish, Ha-Zemanim ba-Halakha p. 375 § 9 and 573 § 3. This ruling is explicitly mentioned in the name of R. Isaac in the book *Ets Hayim*, by R. Jacob Hazzan of London (about 1286) edited by R. Israel Brody; Mossad ha-Rav Kook 1966. The object of this monumental halakhic work was to supplement the *Sefer Mitsvot Gadol* of R. Moses of Coucy. It was the most important halakhic compilation ever written in England.

45 B. Pesahim 2a Tossafot בד"ה והא. In our Tossafot it reads that between the end of the Bein ha-Shemashot of R. Judah and the appearance of (all) the stars there is שעה גדולה. In Tossafot Rashba (R. Samson ben Avraham) the same content is mentioned in the name of "My Master" instead of Ri and the reading is שעה.

46 Like Ravan.

47 Or Zarua, Hilkhot Mila 102 p.51.

of Sabbath, like circumcision or major fasts, he considers that the day ends with the appearance in the eastern sky of the first three medium-sized stars, which occurs while there is still light in the western sky.

- He understood that the division of the day in equinoctial hours is made according to the system of the "Great Clock" or "Nuremberg Clock".[48] Surprisingly,[49] he did not know the system of division of the day in equinoctial hours according the system of the equatorial day used in Jewish calendaric calculations.[50]
- He considered short temporary hours, the night being counted from sunset till sunrise and the day counted from sunrise till sunset.[51]
- He wondered whether the halakhic hours are short temporary hours or if they are equinoctial hours counted according to the system of the "Nuremberg clock".[52]
- He considered a mile of 18m.[53]
- R. Isaac the Elder was also the pupil of R. Tam and we encounter him also

48 B. Eruvin 56a Tossafot בד"ה ואין.

49 Indeed Rashi in B. Eruvin 56a seems well accustomed to it. Furthermore noted scholars of Rashi's school were specialized in the subject and produced important works in the calendaric field: R. Samuel ben Meir and R. Jacob ben Shimshon.

50 Today the passage in B. Eruvin 56a and Shabbat 129a is explained according to this system, without the necessity to consider temporary hours. This solution better fits the length of the Tekufah and it still respects the rule דקאי מאדים בזוגי i.e. that the reign of March is on even hours.

51 This statement results from B. Eruvin 56a Tossafot .בד"ה ואין In this Tossafot, R. Isaac confronted the rules of the tekufot with the time reckoning. It appears that he ignored the time reckoning used in the calculation of the Moladot on the basis of an abstracted equatorial day with night between 6 p.m. and 6 a.m. and day between 6 a.m. and 6 p.m. He could not succeed reconciling the properties of the tekufot with the system of equinoctial hours according to the "Great Clock" system, but he seemed to succeed with the temporary hours. One can prove that this works indeed if we consider 4 successive seasons together on the condition that we consider short temporary hours allowing mutual compensation between the seasons of days and nights. See above table 4.

52 See B. Eruvin 56a, Tossafot בד"ה ואין. When we compare the difficulties raised in both assumptions, we observe that the difficulties raised in the assumption of equinoctial hours according to the Nuremberg Clock are insurmountable; by contrast the difficulties appearing with the short temporary hours seem much less important; the tekufot are not perfectly equal but there is a compensation and therefore no drift at the end of the year. Therefore the conclusion seems to be that the halakhic hours are short temporary hours.

53 If 3 1/3 miles last 60m then 1 mile = 18 m, see note 45.

in discussions were he transmitted or discussed the contradictory position of R.Tam.[54]

4. Tossafot (R. Asher ben Jehiel: Rosh ~ 1250 – 1327)

The position of Rosh is not evident because he seemed to champion two different theories in B. Eruvin and in B. Berakhot. In B. Eruvin 56a[55] he clearly followed our Tossafot and reported the query and the doubt of R. Isaac, whether the day and the night each have 12 temporary hours of variable length or if we consider equinoctial hours counted according to the system of the Nuremberg Clock. In B. Berakhot 3a he championed a day and a night of 12 equinoctial hours.[56] The explanation could perhaps be that the commentary on Eruvin was still written in Germany or at least in accordance with his German background, hence his following of R. Isaac the Elder, while the commentary on Berakhot would have been adapted later according to new notions learned in Toledo about the calculation of the Molad (under the influence of his pupil R. Isaac Israeli). It is also possible that the clock of Toledo worked according to the system of the "Small Clock"; this could have influenced him.[57]

5. The Followers of R. Tam

Besides the French Tossafists who certainly, the majority of them at least, followed the theory of R. Tam, we mostly find followers of his theory among the Provencal and Spanish Scholars. His theory was known and expounded by R. Isaac ben Abba Mari of Marseille and R. Natan ha-Yarhi. It was later championed by Nahmanides, R. Solomon ben Aderet, Meiri, and Ritva who considered that Pelag ha-Minha occurs slightly before sunset.

54 For example in B. Sabbath 35a Tossafot בד"ה תרי, R. Isaac participated to the discussion and did not seem to contradict R. Tam, his teacher!

55 I thank R. Yitshok Silber of Monsey for the indications about Tossafot Rosh on Eruvin and for the exchange of ideas about the problem raised by the contradictory commentaries of Rosh.

56 He must then understand the different examples considered there, the three night guards, the two guards by which David precedes other kings, on the day of the equinox.

57 R. Asher ben Jehiel would then, five centuries before R. Jacob Emden, have understood the Talmudic hours as constant hours according to the "Small Clock" system.

6. The Followers of R. Isaac the Elder

- The German Rabbis did not accept the theory of R. Tam. It is likely that the dependence of their teaching on R. Isaac the Elder of Dampierre is an element of explanation. R. Isaac of Vienna studied together with R. Jehiel of Paris in the Yeshiva of R. Judah Sir Leon, R. Isaac's pupil in Paris. Similarly R. Meir ben Baruch of Rotenburg studied under R. Isaac of Vienna and R. Jehiel of Paris.
- In the commentary Shiltei ha-Giborim[58] on Mordekhay B. Shabbat IV, (3) a statement of a Tossafot (probably in manuscript) is cited which expounds exactly the conception of R. Isaac the Elder.[59] The halakhic hours are short temporary hours counted from sunset to sunrise during the night and from sunrise to sunset during the day. The equinoctial hours are counted according to the "Nuremberg Clock", beginning at sunset and at sunrise; the Sages of the Talmud did not use them.
- R. Judah Sir Leon, in his commentary on B. Berakhot, also addressed the issue but the extant text is only slightly comprehensible.[60]
- R. Eliezer ben Joel ha-Levi[61] followed the position of his grandfather Ravan which is not completely equivalent to that of R. Isaac.[62]

IV. THE POSITION OF MAIMONIDES

The position of Maimonides is a complete, coherent, and well-considered system:

- On Mishnah Pesahim III, 2 he wrote that an average walker covers 1 mile in 24 minutes.

58 R. Joshua Boaz ben Simon Baruch, an important rabbi of the sixteenth century, belonging to the Spanish exiles of Catalonia. He arrived in Italy while he was still young and belonged therefore to the Italian Rabbis. He was the author of Shiltei ha-Giborim on the Rif and Mordekhay (Sabionetta 1554/55). He is also the nearly forgotten author of the Ein Mishpat in all the editions of the Talmud.

59 I thank R. Yitshok Silber of Monsey for bringing to my attention this statement in a text that he is preparing and of which he sent me a draft.

60 See Sinai 37, pp. 87-105. We find apparently in this text arguments in favor of the temporary hours and arguments in favor of the equinoctial hours according to the system of the Nuremberg Clock, but no conclusion.

61 Ravia of Bonn (1140-1225).

62 He used short temporary hours, began Sabbath at sunset but ended it, the festivals and even the minor fasts after the appearance of all the stars. See Sefer Ravia edited by Avigdor Aptowitser, Jerusalem 1964.

- On Mishnah Pesahim IX, 2 he wrote that the distance between Modiin and Jerusalem is 15 miles and an average walker covers this distance in 6 hours.
- In Hilkhot Korban Pesah V, 9 he wrote that anyone removed from Jerusalem on the eve of Pesah at sunrise by 15 miles or more is dispensed from the Paschal offering and is postponed to Pesah Sheni. If the distance is less than 15 miles he can, walking slow, reach Jerusalem in less than six hours.
- In Hilkhot Evel VII, 4 he wrote that a man can cover 40 miles in one day.
- On Mishnah Berakhot I, 1 he wrote that the length of dawn is 1.2 hours and that the altitude of the atmosphere is 51 miles.[63]
- On Mishnah Berakhot I, 4 he wrote that all the hours mentioned in the Mishnah are temporary hours.
- On Mishnah Terumot 7, 2 he wrote that the night begins at the apparition of three medium-sized stars; this occurs [in Palestine, at the equinox] about 20 minutes after [apparent] sunset.
- In Hilkhot Kiddush ha-Hodesh 11, 16 he wrote that the epoch [and the moment of vision of the new moon] is at the beginning of the night and in H.K.H. 14, 6 he wrote that this moment is 20 minutes after sunset.
- In Hilkhot Eruvin I, 12 he wrote that 1 revi'it of water weighs 17.5 dinar or 17.5 * 4.25 = 74.375 gr. Now 1 revi'it = 10.8 e^3, thus 10.8 e^3 = 74.375 cm^3 and e = 1 etsba = 1.9025 cm. Therefore 1 cubit = 6 * 4 * 1.9025 = 45.66 cm and finally 1 mile = 0.4566 *2000 = 913.22m. The celerity of 2.5 miles/hour corresponds to 2.28 km/h; it is indeed a slow walk.

The reconciliation of all these statements and the justification of his mile of 24m, apparently in contradiction with the conclusion of the Talmud was a conundrum, which puzzled the rabbis in all generations.[64]

We propose here a complete and definitive solution to this problem. From the altitude of the atmosphere of 51 miles we deduce that Maimonides followed the

63 In the commentary Tossefot Yom Tov, it mentions a quotation from Sefer Gevurot ha-Shem by R. Solomon Delmedigo, the physician, stating that 51 miles should be 52 miles. Indeed the true value is 51.8 miles, 51 miles is the truncation of this value, which should have been rounded off to 52 miles.

64 The Gaon of Vilna in Shenot Eliahu proposed to ascribe to Rambam the column C of table 5 but he failed to explain the 24m for the mile, R. Schlezinger in Eizehou ben ha-Shemashot and R. Merzbach in Alei Yonah proposed to ascribe to Rambam the column E of table 5 but this would give a solar depression of 15.225° at the end of the astronomical twilight.

Book of Dawn and considered the end of astronomical twilight when the solar depression is 19°.[65] The indication of the length of the astronomical twilight of 72m must be understood as follows: it is measured at the equator, the end of the astronomical twilight is at 7h 16m p.m. i.e. 72 minutes after 6h 04m p.m. true time, which represents the apparent sunset at the equator under Maimonides' assumption that the solar depression is at that moment 1°.[66]

In B. Pesahim Maimonides ruled according to R. Johanan to whom he ascribed column F.

Indeed in B. Pesahim 93b-94a, sunset is the geometrical sunset, when the solar depression is 0°; it occurs on the day of the equinox at 6 p.m. At the end of the astronomical twilight it is then 7h 30m. p.m. true time. One can check that the solar depression is then exactly 19°. The column E cannot fit because it would lead to 7h 12m p. m. corresponding to a solar depression of 15.225°.[67]

The choice of a mile of 24m led Rambam to a BHS of Rabbi Judah of 18m, which he rounded off to 20m in order to take into account the BHS of Rabbi Jose.[68] Again, Maimonides succeeded in getting a perfect coincidence between the beginning of the night as deduced from the Talmud for religious purpose and his definition of the beginning of the night for astronomical observation.

Maimonides' system appears to be perfect, in fact a real tour de force. There remain, however, two difficulties:

1. Maimonides qualified the walker of the eve of Passover as an average walker in Mishnah Pesahim IX, 2 but a slow walker in Hilkhot Korban Pesah V, 9. In fact a celerity of 2.28 km/h is quite slow.
2. Maimonides' solution is accepted by the conclusion of the Talmud. However it rests on an incorrect distance between Modiin and Jerusalem and therefore it was certainly not the solution that Rabbi Akiba taught in the Mishnah. Therefore, despite Maimonides' tour de force, the genuine solution would be according to Rabbi Judah and column C, leading to a mile of 18m, an end of astronomical twilight at 7h 12m p.m. true time and a solar depression of 15.225° and a BHS of 13.5m which would perhaps begin a few minutes (about 5 minutes) after the apparent sunset in order to correspond with the beginning

65 See J.J. Ajdler, "Talmudic Metrology II: The Mile as a Measure of Time", B.D.D. 20 (2008), pp. 25 – 28.

66 Today we consider that the solar depression at the apparent sunset is 0.85°.

67 It appears that the precision given by Maimonides about the altitude of the atmosphere happens to be essential for the correct exegesis of Maimonides.

68 According to the ruling of Rabbi Johanan B. Shabbat 35a.

of the night about 20m after the apparent sunset.

V. THE EQUINOCTIAL HOURS OF R. ISRAEL ISSERLEIN ARE COUNTED ACCORDING TO THE "SMALL CLOCK" SYSTEM

1. The Position of R. Israel Isserlein

The revolutionary positions adopted by R. Israel Isserlein in his responsa plus an incorrect understanding of his terminology raised endless discussions. However his responsa contain enough information to properly and completely understand his system.

- Only in responsum I, 1 he considered temporary hours in order to try justifying the early evening prayer of the German communities. It appears clearly that he counted these temporary hours from sunrise till sunset.[69]
- R. Israel Isserlein certainly used in practical life equinoctial hours and apparently did not practically know the temporary hours.
- In his system of equinoctial hours, these were apparently counted according to the system of the "Small Clock".[70]
- R. Israel considered that the hours of the Talmud are equal hours. Normally they were counted from sunset and sunrise but in some cases[71] we can count them backwards from noon. Similarly Pelag ha-Minha is 1.25 equinoctial hour before sunset.[72]

69 Neustadt has a latitude of 47.8 °N and at the solstice δ = 23°; 30'. The geometrical sunset is at 7h 55m p.m and the length of the day is 15h 50m. R. Isserlein was asked about the practice of communities to pray Ma'ariv between 3 and 4 hours before the night. Let us consider for a first approach an extended day of (40/32) * 15.83h = 19.79h. R. Isserlein did certainly not intend the length of an extended day but the day itself. He wrote that there are areas were the length of the day is 18h; this must certainly be in areas north of Neustadt-Vienna. At the latitude of 58.5° the geometrical sunset is at 9 p.m. and the length of the day is 18h. Pelag ha-Minha is (1.25/12) * 18 = 1.875h = 2h – 1/8h before sunset as mentioned by *Terumat ha-Deshen*. In conclusion it appears clearly that the length of the day of 18h is necessarily considered between sunrise and sunset and Pelag ha-Minha is (1.25/12) of this day before sunset. He calls sunset: Tseit ha-Kokhavim! It appears that the communities prayed Ma'ariv between 3 and 4 hours before sunset and he could barely justify two hours.

70 Indeed on the late Erev Purim, on March 25, the clock of Neustadt rang 5 p.m. just after Pelag ha-Minha.

71 On the eve of Passover, see responsum I: 121, for fixing the moment when eating bread becomes forbidden, we can count two hours backwards from noon, leading to 10 a.m.

72 In responsum I, 109 he deals with the early reading of the Megila on the eve of Purim when it occurs very late with regard to the season and the solar year. In our modern

- He considered that 1 mile represents 18 minutes.[73] This seemed a revolutionary position.[74] Most of the rishonim considered a mile of 22.5 m and Maimonides defined the mile as 24m. He understood then B. Pesahim according to column C. The 40 miles are covered in one day of 12 equinoctial hours before sunrise and sunset.
- He calls sunrise Alot ha-Shahar and sunset Tseit ha-Kokhavim. This terminology is surprising and it misled generations of rabbis who did not check the numerical data provided by him and rested on his misleading terminology. The origin of this terminology is a real conundrum.[75] R. Isserlein could have been influenced by the terminology of Ravia[76] who designated sunset (12 hours) by "night" and the "appearance of the stars".[77]

Gregorian calendar this day can fall the latest on March 25. With a latitude of 47.8°N and $\delta = 1.75°$ we find that geometrical sunset is at 6h 08m. Pelag ha-Minha is 1h 15m before at 4h 53m. If we had considered apparent sunset we would find 6h 13m – 1h 15m = 4h 58m thus slightly before 5 p.m. true time as mentioned by his pupil in Leket Yosher. At that period, the clock of Neustadt gave the true time.

In responsum I, 121 it deals with the time schedule of the eve of Passover when it occurs very late with regard to the solar year. This day can fall the latest on 25 April. With a $\delta = 12°; 45'$ we find that the geometrical sunset is at 6h 58m and the apparent sunset is at 7h 03m p.m. The length of the day is about 14 h and the morning lasts 7h. Thus as R. Isserlein noted, at the end of the fourth hour of the day (after sunrise) we are 3 equinoctial hours before noon. R. Isserlein rules that we could consume leaven until 10h a.m. two hours before noon.

73 Responsum I, 167.

74 In fact this was less revolutionary as it could be imagined as we saw above that this was already the position of R. Isaac the Elder; see above note 53.

75 R. Zalman Koren in the paper mentioned above in note 39, went even further and, in order to explain the theory of R. Isserlein, wanted to ascribe to R. Isserlein the same mistake as he ascribed to Tossafot, to believe that on the day of the equinox the extended Jewish day is equal to its corresponding night. This assumption is still more unlikely because R. Isserlein had at his disposal the great clock of Neustadt which allowed him to assert that the spans of time between sunrise and sunset and between sunset and sunrise are equal on the day of the equinox and nothing else. But what is quite possible is that R. Isserlein ascribed the theory of R. Koren to Tossafot. Now, R. Isserlein was aware of its material error but he accepted its practical conclusions that the mile corresponds to 18m. He continued to use the terminology of Tossafot but with a new corrected meaning: Alot ha-Shahar must be understood as sunrise and Tseit ha-kokhavim as sunset in order to get the equation: 40 miles = 12 average hours. This could be an explanation for the peculiar terminology of Terumat ha-Deshen, which would be the origin of the confusion and perplexity surrounding the ruling of R. Isserlein.

76 He quotes Ravia in responsum 1.

77 Sefer Ravia, Avigdor Aptowitser, Jerusalem 1964, Vol 1 p.1.
He writes that pelag ha-Minha is at 10h45m and 12h is the night i.e the appearance of the

It is thus certainly an irony of history that the tradition ascribed to him, and named after him, the system of Jewish long temporary hours, which he never even considered.

The position of R. Isserlein was certainly influenced by the time reckoning of his area. Especially important was the fact that the indications of the clock of Neustadt were given in equinoctial hours according to the "Small Clock" system. His understanding of the hours of the Talmud as equinoctial hours was revolutionary. These hours in the Talmud were counted separately for the day and the night according to the "Nuremberg Clock" or "Great Clock".[78] Regarding the temporary hours, he seems to have had recourse to them in a case of emergency[79] and did not differ from his German predecessors who used the short temporary hours (Ravia and Maharil).

2. The Followers of R. Israel Isserlein

The followers of R. Isserlein were always persuaded that he used long temporary hours. R. Abraham Pimentel in Minhat Cohen called the long temporary hours, "the method of Terumat ha-Deshen" while the short temporary hours were called "the method of Levush". At the end of the eighteenth century, R. Elijah, the Gaon of Vilna, still took issue with R. Isserlein on that subject.

VI. THE PUBLICATION OF THE SHULHAN ARUKH

The publication of the Shulhan Arukh at the beginning of the development of printing considerably increased its impact. It was the origin of a homogenization of the Jewish rules and customs and of the disappearance of local practices. The Shulhan Arukh ruled according to R. Tam on the issue of the beginning and end of Sabbath, of the holydays and of the fasts. It ruled also that the mile is 18m. However the position of Shuhan Arukh is not the clearest, and in the end raises some doubts;[80] furthermore it did not raise the issue of the time reckoning during

stars. But we know that he accepts Sabbath at sunset and counts the hours of the eve of Passover through the position of the sun.

78 In the same way as R. Isaac of Dampierre in B.Eruvin p.56a, Tossafot בד"ה ואין בין תקופה.

79 In responsum 1 in order to try justifying the practice of the communities to pray so early.

80 How did R. Karo understand R. Isserlein? Did he understand in responsum 1 that he counts temporary hours from dawn till dusk? Then his 18 minutes are temporary minutes and represent in fact 22.5 equinoctial minutes. Or did R. Karo understand that R. Isserlein counts the temporary hours from sunrise till sunset? Then indeed the 18 minutes are

the Jewish religious day.[81] Finally, this publication did not bring an end to the discussions and controversy. The problem of the limits of Sabbath and of Jewish time reckoning remained a subject in perpetual discussion and evolution until today.

VII. THE HOURS OF THE TALMUD ARE EQUINOCTIAL HOURS ACCORDING TO THE "SMALL CLOCK" SYSTEM

R. Israel Isserlein was the first[82] to consider that the hours in the Talmud are equinoctial hours. These hours were counted, at first glance, according to the system of the "Great Clock".[83] It was necessary to use pre-calculated tables to know the length of the night and day. In this system the number of hours from sunrise until noon changed during the year and this was the origin of the problem raised before R. Isserlein: when leaven may be consumed until the fourth hour and we have seven hours in the morning should we stop consuming leaven after 4 hours after sunrise i.e. at 4 hours in the day or two hours before noon, at 5 hours in the day.[84] However, from the comments of Leket Yosher on responsum 109, that Pelag ha-Minha on March 25 is at 5 p.m. we can deduce that his clock, the clock of Neustadt, worked according to the "Small Clock" system. It is only for the examination of the time schedule of the eve of Pessah that he must count the number of equinoctial hours from sunrise until noon.

With time, the "Small Clock" system asserted itself and became commonly used: the system worked on the basis of the dual sequence of 12 hours which we still use today, from noon to midnight and from midnight to noon. It had to be set only once a day at noon, without using any table. In this system 6 a.m. represents the boundary between night and day. It is thus assumed that the end of the third hour is 9 a.m. and the end of the fourth hour is 10 a.m.

It is interesting to see how this small change in time reckoning changed people's

expressed in equinoctial time. In fact R. Isserlein, except in this responsum 1, never used temporary hours.

81 In Shulhan Arukh, the manner of calculating the temporary hours is not raised.

82 Except probably the Rosh in B. Berakhot 3a.

83 Indeed the morning hours seem to be counted from sunrise; see responsum I: 121 on the eve of Pessah.

84 Terumat ha-Deshen counted the Halakhic hours as equinoctial hours apparently according to the system "Great Clock" exactly as did R. Isaac the Elder of Dampierre in B. Eruvin 56a, Tossafot בד"ה ואין for the non-halakhic equinoctial hours in which he wanted to consider the 91 days and 7.5 hours of a tekufah.

mentality. Soon the rabbis forgot the former system and they reinterpreted the Talmudic rules according to the new system, which they considered as natural as if it had always existed. R. Jacob Emden highly valued his achievement and dwelled upon the subject in his books.[85] He argued that the sleep and the appetite of people are regulated on a fixed hour basis and not according to temporary hours.[86] Therefore he understood in Mishnah Berakhot I, 2 and in Mishnah Berakhot IV, 1 that 3 and 4 hours must be understood as 9 a.m. and 10 a. m. referring to a standard day, the day beginning at 6 a.m. and the night beginning at 6 p.m. The difference between R. Jacob Emden and R. Israel Isserlein thus turns on the manner of counting the equinoctial hours.

VIII. THE HOURS IN THE ZOHAR AND TIKKUN HAZOT

In the introduction of the little book of special prayers Sha'arei Tsion[87] the author, R. Nathan Neta Hannover[88] (d. 1683) wrote that the Tikkun Hazot must be said 6 hours after the beginning of the night.[89] He proved his position referring to the writing of R. Haïm Vital. R. Abraham Gombiner (1637-1683) wrote in Magen Avraham on O.H. 1, and O.H. 233.1, referring to the Zohar, that for calculating midnight we consider a night of 12 hours. In the first quotation he referred to Sha'arei Tsion and followed certainly this opinion.

R. Jacob Emden challenged sharply this position and considered it illogical and in contradiction with the Zohar.

In fact the Zohar considered that the 12 hours symmetric with regard to midnight belong to the night and the 12 hours symmetric with regard to noon

85 *Lehem Shamayim* on Mishnah Berakhot I, 2. And *Mor U-Ketsiyah* on Orah Hayim I.

86 R. Jacob Emdem certainly considered the situation in his town of Hamburg, latitude 53.5° N where the ratio of the longest to the shortest daylight hours is 2.29: 1. In Palestine, this ratio is only 1.42: 1. The drawback of the use of temporary hours was much more limited and we know that in Rome and Athens civil life was organized around temporary hours. This limits considerably the pertinence of his argumentation. In Rome, despite a ratio between the longest day and shortest day of 1.73: 1, civil life in the antiquity was organized around the temporary hours and, by contrast with the arguments of R. Jacob Emden, the main meal was taken at the 9th hour; see note 2. R. David ha-Levi (1586-1667) (Taz) in Magen David on O.H. 443 argued also that the meals are taken at a fixed temporary hour.

87 Prague 1662.

88 נתן נטע בן הקדוש מוהר"ר משה הנובר זצ"ל הי"ד אשכנזי החונה על דגלו פק"ק יאשי לע"ע

89 וצריך אתה לדעת שזמן חצות לילה הוא שוה בין בחורף בין בקיץ, זמנה אחר שש שעות בלילה וכן מוכרח בזוהר ר"פ ויקהל

belong to the day. This is exactly the point of view adopted in the system of counting the Molad, as if we were at the equator. Thus, according to R. Jacob Emden, who worked in true time,[90] midnight is really the middle of the night, when the sun is on the plane of the meridian (lower transit).

IX. THE TALMUDIC RELIGIOUS DAY IS DISSYMMETRICAL

Some rabbis did not follow the theory of R. Tam about the late limits of the day, and began Sabbath at sunset and ended it at the appearance of the first medium-sized night stars. They considered however the temporary hours of a Jewish day beginning at daybreak and ending at the appearance of the first night stars. This Jewish day corresponded certainly to the description of Nehemiah as mentioned in B. Berakhot I, 1, i.e. the working day as considered in antiquity. They adopted the principle of temporary hours of a theoretical Jewish day as championed by R. Tam but they objected to the theory of R. Tam, extending the day until the end of the astronomical twilight, 4 miles after sunset. This day thus began 4 miles before sunset and ended about 1 mile after sunset; this day was no more symmetrical with regard to noon, the moment of culmination of the sun. In fact, the middle of this day precedes noon by about 1.5 miles or about half an hour. In principle this contradicts a Talmudic requirement that the beginning of the 7th temporary hour must correspond to the sun's culmination. This system was however championed by many authorities.

Rabbi Nathan Adler,[91] as reported by his two disciples R. Moshe Sofer of Pressburg[92] and R. Abraham Bing of Wuertzburg[93] considered that hazot was at 11 a.m.[94]

R. Mordekhay Karmi[95] wrote in Ma'amar Mordekhay that hazot is about a half hour before noon.[96]

This system was adopted by R. Tuckazinski in the Luah Erets Israel until 1924,

90 True time refers to true sun while mean time refers to mean sun. During the nineteenth century the civil time of the European nations passed progressively and in scattered order from true time to mean time.

91 1741 – 1800.

92 1762 – 1839.

93 Renowned talmudist : 1752 – 1839.

94 Apparently true time. This statement cannot be justified and remains incomprehensible.

95 France: Carpentras 1749 – Aix-en-Provence 1825. He was the author of Ma'amar Mordekhay on Shulhan Arukh, Leghorn, 1784 – 1786.

96 Ma'amar Mordekhay on O.H. 233.3, Livorno 1788.

when he decided to adopt a religious day extending for 4 miles before sunrise and 4 miles after sunset. The purpose of the transition was certainly to get a symmetrical day, and the end of the sixth hour coinciding with true noon. He could, however, have achieved this if he had considered the end of the sixth hour at true noon and different temporary hours in the morning and the afternoon, the morning hours being longer than the afternoon hours because of the early daybreak. Strangely enough, this logical system was never proposed.

X. THE INTRODUCTION OF THE NOTION OF SOLAR DEPRESSION IN THE DEFINITION OF THE LIMITS OF THE DAY

We mentioned already above that Maimonides in his commentary of Mishnah Berakhot I, 1, certainly followed the author of the Book of Dawn by estimating the altitude of the atmosphere to be 51 miles, certainly a truncation of the exact value of 51.8 miles corresponding to a solar depression of 19°. It is also important to note that Maimonides considered three types of hours: the equinoctial hours, the temporary hours and the corrected hours. He used the latter to characterize the length of the astronomical twilight or in other words a span of time depending on a constant solar depression.[97]

This was an exceptional achievement that was never recognized for its true value. Maimonides thus considered that the astronomical twilight was reached when the solar depression is 19° and he was perfectly aware of the special character of the length of the spans of time connected to a fixed solar depression. R. Solomon Delmedigo understood it also very well and commented on Maimonides' commentary on Mishnah Berakhot I, 1. These elements are still ignored today by practically everyone. It would be Raphael ha-Levi of Hanover's role to be at the origin of the greatest revolution in the calculation of the Sabbath's limits. Without realizing it, or even having an inkling of it, he was at the origin of a profound modification in the calculation of the Jewish evening times through the introduction of the concept of solar depression. While the preceding generations generally determined the end of Sabbath by an experimental way, without the use of tables, and they thought that these times must be evaluated in temporary hours, Hanover was the first to establish a perpetual table giving all through the year the time of the appearance of three medium-sized night stars.[98]

97 Halakhic Times, Leo Levi, Rubin Mass, Jerusalem 1992, p. 42.
98 See a copy of it in Ha-Zemanim ba-Halakha, Benish, 1996, p. 525.

Hanover was not the first to know that the phenomenon of the appearance of the night stars depends on the darkness, which in turn depends on the solar depression.

It was, however, Hanover who established the first table for this purpose, and who actually originated the practical use of such tables. R. Hirshel Levin[99] and his son Solomon Hirshel[100] used and expanded this table in Berlin.[101] R. Nathan Adler used and extrapolated it incorrectly to Frankfurt am Main, R. Moshe Schreiber (Sofer) extrapolated it even to the town of Mattersdorf.[102]

The use of tables was not immediately accepted; leaflets circulating against R. Nathan Adler and his strange practices criticized also his using of tables allowing him to determine in advance the end of Sabbath.

However, today the concept of solar depression is universally accepted. Although the theory of R. Tam is not generally the rule, the Jewish hours are often calculated according to the principle introduced by R. Tam,[103] considering at the equinox an extended day of 4 miles or 72 m before sunrise and after sunset. It is today accepted that the calculation all through the year is performed according to the principle of the constant solar depression. Even those who follow R. Tam rigorously[104] generally accept applying it according to the concept of the solar depression.

XI. THE MODERN SITUATION

Sabbath begins at sunset, but practically it begins from 18m to 30m before and it ends between one to two miles after sunset, but the Jewish time table is constructed on the basis of an extended day beginning 4 miles before sunset and

99 The rabbi of Berlin: 1721 – 1800.

100 The rabbi of London: 1762 – 1842.

101 They calculated temporary hours for an expanded day with a late daybreak (solar depression of 8°; 5') and an early dusk (solar depression of 7°; 05'). Hazot was thus slightly before noon. See a partial copy of it in Ha-Zemanim ba-Halakha, Benish, 1996, p. 526.

102 See Responsa Hatam Sofer: Orah Hayim 80.

103 In other words we follow the method and the principle of R. Tam but if he was present today he would not understand at all what we ascribe him because the method ascribed to him evolved in the meantime.

104 Most of them satisfy themselves with a constant delay of 72 or 90 m after sunset, but according to the original theory these were temporary minutes.

ending 4 miles after sunset.[105]

Despite the ruling of Shulhan Arukh in accordance with R. Tam about the limits of Sabbath, the issue remained open. Similarly the issue of the religious time reckoning did not receive a final ruling. There is however a connection between both issues: normally those who accept an early beginning and end of Sabbath (Geonim) should count short temporary hours and those who accept a late beginning and end of Sabbath (R. Tam) should count long temporary hours. Still R. Mordekhay Jaffe followed R. Tam for the limits of Sabbath but counted short (astronomical) temporary hours. But we never saw people following the Gra for the issue of Sabbath and counting their temporary hours according to the theory of Tossafot.[106]As surprising as it may be, the unthinkable is today the rule in many communities. The accepted limits of the Sabbath are today calculated according to the Gra, but on various time tables available on the Internet, the latest time for Shema and for prayer is given according to the Gra but also to the Magen Avraham.[107] I have no satisfactory explanation for these contradictory practices. If, in Israel, you accept Sabbath at sunset or earlier and end Sabbath between 26 and 36 minutes after sunset, it makes no sense to count the religious hours of the day according to the temporary hours of a fictitious day beginning, on the day of the equinox, 72m before sunrise and ending 72m after sunset.

XII. CRITICAL ANALYSIS OF MODERN JEWISH TIME TABLES[108]

The modern time tables published nowadays are influenced by the publication of the book Or Meir.[109] According to this book, Alot ha-Shahar or daybreak is on the day of the equinox and at the latitude of Jerusalem at 4h; 44m a.m. true time corresponding to a depression of 16.1°[110] and the end of Sabbath is at 6h; 40m p.m. true time corresponding to a solar depression of 8.5°.[111] There is a basic contradiction in these statements.

105 There are still communities working with natural temporary hours (between sunrise and sunset) like the Gra. However many "hareidim" adopt the long temporary hours which in the morning and on the eve of Pesah are more stringent.
106 People speak of the method of calculation of Magen Avraham.
107 According to the usual terminology.
108 Including tables on the web like MyZmanim, chabad.org, Mobile Zmanim, Kosher.org.
109 Meir Posen, London, 1973.
110 Four miles before sunrise. In Or Meir p. 314 he writes 16.2°.
111 Two miles after sunset, according to Birkei Yossef, see Or Meir pp. 218 and 222.

Indeed, while in B. Sabbath 34b-35a sunset represents the apparent sunset, refraction and apparent dimension included, and represents the moment of the apparent disappearing of the upper limb of the sun's disk, in B. Pesahim 93b- 94a sunrise and sunset correspond to the geometrical sunrise and sunset, at 6 a.m. and 6 p.m. true time on the day of the equinox.[112] Therefore daybreak is 4 miles before geometrical sunset, at 4h; 48m a.m. true time in Jerusalem at the equinox and it corresponds to a depression of 15.225°. Similarly, the end of Sabbath in Jerusalem, according to Birkei Yossef, is when the sun is "in the middle of the thickness of the firmament", two miles after geometrical sunset at 6h; 36m p.m. true time when the solar depression is 7.65°. For the record, Maimonides considered a theoretical end at 6h; 24m and R. Raphael ha-Levi from Hanover at 6h 34m.

For the same reason the long temporary hour on the day of the equinox is 8m /12 = 45 s too long. Similarly the short temporary hour should be calculated on the basis of the geometrical sunrise and sunset and not the apparent sunrise and sunset, thus on the day of the equinox, on a day of 12h and not 12h; 08m.

XIII. CONCLUSIONS

The issue of the notion of the hour and of time measurement in the Talmudic and rabbinic literature is an interesting case of the influence of a slow and hardly perceptible evolution of the principles of time measurement. This evolution was slow enough that the Talmudic commentators and the rabbinic authors generally understood the related Talmudic quotations according to the principles and understanding of their own specific periods. The fact that the first important commentators wrote their commentaries at a time when temporary hours were still used in practical life explains why they succeeded in seeing the original signification of the main Talmudic passages related to the definition of the important moments of the religious day as following the principle of the temporary hours. An important change took place in the history of the understanding of the Talmud in relation to time measurement and the moments of the religious day. In the second half of the twelfth century, R. Tam created a new concept of the temporary hour calculated as the twelfth part of a Jewish halakhic day corresponding to an

112 This is the only way to have the equality of day and night at the equinox. Furthermore the traveler on the eve of Passover covers the distance between Modiin and Jerusalem exactly in 6 hours, between 6 a.m. and noon (Maimonides) or between noon and 6 p.m. (Rashi).

extended day from dawn (4 miles before sunrise) until dusk (4 miles after sunset). This new concept was purely theoretical and did not rest on any aspect of practical life, and was probably not intended to have practical consequences. However it asserted itself strongly and had a considerable influence on the understanding of the Talmud and on the practical Halakhah.

Finally, it must be noted that knowledge of the different manners of counting the equinoctial hours is necessary to comprehend the rabbinic writings related to time reckoning, which generally used the local conventions of their specific periods without any explanation; they were considered useless and superfluous.