Myths and Maths of the Blessing of the Sun

1. Introduction

As I write this, I am making plans to attend one of the many Birkat Hachama ceremonies to be held all over the world this Wednesday (2009, March 26, **Julian** / 2009, April 8, **Gregorian** / 5769, Nisan 14, **Hebrew**). However, unlike many others who will take part in this rarest of liturgical observances in the Jewish calendar, an event that occurs only once every 28 years, I will, sadly, be under no illusion that I will be witnessing the Sun's return to the same place in the sky that it occupied when it was created. I say sadly, because the innocence of that understanding of the event imbues this ceremony with a certain fascination, a certain magical quality, which is somewhat dispelled by the more factual understanding of the subject that one acquires from a more thorough and rigorous study of the Jewish calendar, which has been a lifelong hobby of mine.

Despite the name of the ceremony, we will not be blessing the Sun itself; we will be blessing God for the Sun and the cycles of nature associated with it, for which, I should like to point out, we may thank the fact that the Earth's axis of rotation is tilted at an angle of 23½° from the perpendicular to the plane of its orbit around the Sun. If not for that single, most fortuitous miracle of all creation, for Earth's inhabitants, those cycles would not exist. Life on our planet and the natural environment as we know it would be vastly different. There would be no seasons, and we would not have a Birkat Hachama, which is associated with the change of seasons that begins anew each year with the March equinox.
See: http://www.youtube.com/watch?v=o1bZb9AXdrI

That is the wonder of creation that I will be thinking of when I recite the central and essential part of the Birkat Hachama ceremony – **the blessing** *(oseh maasei bereshit)* praising God for "performing acts of creation." I use the plural ("acts") because that is the true sense of the overall purpose of this blessing, which brings us immediately to the first myth of Birkat Hachama:

2. Criteria for reciting this blessing and when it is to be used for Birkat Hachama

Myth The above blessing is recited only once every 28 years.

Fact This blessing is also prescribed for the sighting of other natural phenomena such as "shooting stars" (i.e. meteors) in the night sky, and seeing lightning. If one observed this religiously, reciting the blessing whenever one of the specified phenomena occurred, he would recite this blessing far more often than once in 28 years. It is true however that the specific ceremony of Birkat Hachama occurs only once in 28 years.

The criterion for when this blessing is to be recited over the Sun is expressed simply as "one who sees the Sun at its *tekufa*", meaning the equinox. There is nothing in the actual wording of this dictum that specifies that this only applies to the "spring" (i.e. March) equinox, and that even then it only applies when the time at Jerusalem[1] of its occurrence is on a Wednesday, at the beginning of the day (i.e. at zero hours), by Jewish time reckoning. Nevertheless, this is the halachic interpretation that has been overlaid on this dictum, limiting the applicability of this criterion.

Maths Note that "zero hours" here means zero hours, **Jewish Mean Time (JMT)**, i.e. as the hours of the day are counted in the Jewish calendar in which the date changes at mean sunset, not six hours later at midnight when the civil date changes. So Wednesday, 00:00, JMT = Tuesday, 18:00, civil time, and in general, **JMT** (anywhere) **=** (local) **civil time + 6 hours**.[1]

3. Religious and cultural significance of Birkat Hachama

This limiting interpretation deserves some explanation. Why only the March equinox, and what is the significance of Wednesday? The simple answer is that the March equinox is regarded as the "birthday" of the Sun and when this birthday occurs on a Wednesday at the very beginning of the day, it is regarded as a very special birthday (like someone turning 13 or 21 or 50) because in the biblical account of creation in chapter 1 of Genesis, the first book of the Torah, the Sun was created on a Wednesday. I do not know the origin of the notion that this occurred at zero hours (JMT) on that day. Perhaps the significance of that time is just that the beginning of a day is regarded as the moment of its "birth", so when the equinox occurs at that time on a Wednesday it occurs at the birth of a special birthday.

I will probably be branded a heretic for saying this, but the notion in Jewish tradition and folklore that the Sun's birthday is the March equinox probably comes from the influence of other surrounding cultures. The notion that the March equinox is the beginning of the tropical year (a full cycle of seasons) is commonplace in the popular culture of all ancient peoples of the northern hemisphere, and it has especially prominent significance in agrarian societies, where it is the beginning of the agricultural year. It heralds the arrival in that hemisphere of spring, a time in nature of renewal, new growth, and fecundity. This time was often celebrated in pagan religions with fertility festivals. It is a time of many beginnings. If one was to nominate a "birthday" for the Sun, it would have to be the spring equinox. Even in modern science, the March equinoctial point on the ecliptic (this will be explained later) is a defining reference point for coordinates of positional astronomy. This convention is probably rooted in the cultural notions I have just mentioned.

The "official" explanation is that the world was created in the spring, but this is actually a subject of debate in the Talmud, where the opposing view that the world was created in the autumn (near the time of *Rosh Hashana* in the Jewish calendar) seems to have gained wider acceptance, and this is reflected in our calendar and in the liturgy of *Rosh Hashana*. I say that whichever view is correct, it can only be half correct. Only half of the world could have been created in the spring; the other half was created in the autumn. (Think about it.)[2]

> (This brings up an important point regarding the naming of the equinoxes. Those two times of the year used to be called by astronomers the "vernal" (spring) equinox and the autumnal equinox. Nowadays, especially in Australia, we use the more unambiguous international terms, the March and September equinoxes, seeing that it is only in the northern hemisphere that they mark the beginning of spring and autumn respectively. From now on, I will stick to the modern usage and refer to them only as the March and September equinoxes.)

So, getting back on topic, it seems to me that Judaism has replaced the pagan practices of marking the Sun's birthday with rituals celebrating the Sun (and other forces of nature) as powers in their own right and instead created a God-centred ritual that emphasises our belief in a Creator who is Master of the forces of nature. We thank God for the Sun and the cycles of nature associated with it by praising God for His acts of creation. This is why we attach such special significance to the occurrence of the Sun's birthday on a weekday and time that reminds us that God created the Sun and recite the Blessing for the Sun only on those occasions.

4. The Nature of the Observance and its Seasonal Character

A noticeable feature of Birkat Hachama is that it is held, naturally enough, outdoors in the sunlight, and it is customary (largely because of the sense of specialness about the occasion on account of its rarity) to organise large gatherings for this ceremony.

Thinking of this brings to mind a scene that I once witnessed when driving past the Greek Orthodox church that is just down the road from me. There was a large group of people gathered in the front courtyard, standing there quietly for quite some time – clearly an overflow crowd for some important service. I was curious about this, puzzled by the date – it was two weeks after Easter. Then I realised what denomination the church was and understood that they were celebrating the Orthodox Easter. "They must still be using the Julian calendar," I thought.

I later learned that this is no longer the case, but for a long time (until 1924), the Orthodox church did not recognise the calendric reforms of 1582 by Pope Gregory 13th, and continued using the old Julian calendar for its religious holidays. Some breakaway Orthodox churches (the "Old Calendarist" churches) still do. (The main reason, nowadays, why Orthodox Easter is often delayed is because their Easter may not occur during Pesach.) Even now, they still do not use the Gregorian calendar. In 1924 they adopted a Revised Julian Calendar whose dates currently coincide with the dates of the Gregorian calendar, but because their leap year rules differ slightly, this will only be the case until the year 2800.

The Julian calendar (named after Julius Caesar, who introduced it in 45 BCE)[3] is now 13 days behind its reformed version, the Gregorian calendar (the present-day civil calendar that is now in almost universal use). The Julian calendar's mean year-length, 365¼ days, is longer than the mean length of a tropical year (a full cycle of seasons) and the accumulating difference, year after year, caused the commencement of the seasons to gradually shift to progressively earlier dates in the Julian calendar. This drift was a problem for the Church because Easter, like Pesach, is a (northern) spring festival and must occur shortly after the March equinox, but in 325 the council of Nicaea had irreversibly linked

Easter not to the equinox itself, but to March 21, assuming that to be its permanent date. By 1582, that drift had amounted to 10 days so that the equinox was no longer occurring on March 21 but on March 11. To correct this, Pope Gregory 13th instituted a calendar reform. (Unable to change the rule, he had to make the calendar more accurate instead.) As a one-off adjustment, 10 days were dropped from the calendar of that year. In addition, he changed the leap year rules, which shortened the calendar's mean year length to 365.2425 days, much closer to the mean length of a tropical year. The difference between the Julian and Gregorian calendars, which was only 10 days in Pope Gregory's time, and 11 days in 1752, when Britain and its American colonies switched calendars, grows by 3 days every 400 years, and is now 13 days.

On seeing that crowd gathered for Orthodox Easter, and assuming that they were still using the old Julian calendar, I thought, "why don't they get with the times and realise that they are observing their holidays two weeks out of season?" And then I thought of our own Jewish ceremony of Birkat Hachama, the dates of which are based on exactly the same calendar – the Julian calendar. And this brings us to the next myth of Birkat Hachama:

Myth Birkat Hachama is observed when the Sun returns to the same position in the sky (as seen from Earth) that it was in when first created.

Although I will soon show why this is a myth, it nevertheless deserves some additional explanation. Specifically, what is the position in the sky that we speak of here? That position is a certain point on the **ecliptic**, the imaginary circle in the sky where the plane of the Earth's orbit cuts the **celestial sphere**. This is an imaginary sphere of some arbitrary, immense diameter surrounding the Earth and concentric with it. In positional astronomy, the heavenly bodies are imagined to be located on the inside surface of that sphere. During the course of a tropical year (a full cycle of seasons), the Sun appears to travel around the ecliptic from west to east at the rate of just under 1° per day, passing through the twelve constellations of the zodiac as it does so. This apparent motion is an illusion produced by the real motion of the Earth's annual orbit of the Sun. Twice a year in the course of its apparent annual motion around the sky, the Sun is at one of the two **equinoctial points** that lie on this imaginary circle. They are the two points where the ecliptic is intersected by the plane of the Earth's equator if we imagine that plane to be extended outwards all the way to the celestial sphere. (See illustrations below.)

When the Sun is at the March equinoctial point, it is passing from the southern hemisphere to the northern hemisphere – the beginning of autumn here in Australia. When it is at the September equinoctial point, it is passing from the northern hemisphere back to our hemisphere and it is the beginning of spring for us. Of course, this is not due to any motion on the part of the Sun; it is due to the motion of the Earth in its annual orbit of the Sun. (That, combined with the tilt of its axis.)

So the notion is that when the Sun and Earth were created, the Earth was placed at that position in its orbit that coincided with the March equinox so that the Sun, as seen from Earth, was at the March equinoctial point on the ecliptic.

Fact Although Birkat Hachama is observed approximately (*very* approximately) around the time of the beginning of northern spring, it has never occurred and never will occur on the day of the actual March equinox. (This year, for example, the equinox occurred on March 20, Gregorian, at 11:44 UTC.) Nor has the Sun ever been in exactly the same position anywhere on the ecliptic at any two instances of Birkat Hachama. This was well known even to Shmuel.

5. Its Place in the Calendar: *Tekufot* Shmuel, the Shmuelian Nominal Equinoxes

Who is this Shmuel and what does he have to do with it? It is **Shmuel Yarchinai**, a Talmudic rabbi and astronomer of the third century. *Yarchinai* (which means something like "moon gazer" or "lunar expert") was a title or honorific bestowed upon him in recognition of his astronomical skills and his interest in fixing rules for a permanent Jewish calendar – a development that did not even begin until about a century later, but he was one of the pioneers of it.

And what does Shmuel have to do with it? Well, it was his calculations that were adopted by the Jewish calendar for the timing of two seasonal liturgical observances in Judaism. One is Birkat Hachama and the other is the annual commencement, for diaspora Jewry, of the *sh'ela* season, the period during the year corresponding to the rainy season in Israel during which we add a request for rain to our daily prayers. Since both of these observances are seasonal in nature, they have no fixed dates in the Jewish

calendar, whose months are lunar. They are the two "moveable feasts" of Judaism (if I may borrow the term). Instead of having fixed Jewish dates, these observances are linked to the two equinoxes. Birkat Hachama is linked to the March equinox as explained above and *sh'ela* is linked to the September equinox. For diaspora Jewry, *sh'ela* commences each year 59 days after the Shmuelian September equinox. Birkat Hachama occurs whenever the Shmuelian March equinox occurs at zero hours (JMT)[4] on a Wednesday.

The Hebrew equivalent for this term "Shmuelian equinox" is ***tekufat Shmuel***, but what does it mean? Well, the first thing to keep in mind is that it is a purely calendric term, not an astronomical term. (This distinction is very important.) Secondly, the word *tekufa* and its plural *tekufot*, can, depending on the context, mean either season or one of the four "turning points" in the tropical year that mark the change of the seasons, the March and September equinoxes and the June and December solstices. Since the two observances mentioned above have no fixed Jewish dates, Shmuel Yarchinai wanted to simplify the method of ascertaining the dates on which they should be observed. To this end, he devised a method of calculating the seasons which had the deliberate effect of pegging these observances to fixed dates in the Julian calendar, which by Shmuel's time had been in widespread use throughout the Roman empire for over two centuries, and, importantly for this purpose, was a solar calendar.

With this in mind, Shmuel adopted **Sosigene**'s estimate of the mean length of the tropical year, namely 365¼ days, which was also the mean year-length of the Julian calendar. He divided this period by 4, to obtain a mean season-length of 91 and 5/16 days, i.e. 91 days, 7.5 hours. This is therefore a fixed interval between any Shmuelian *tekufa* (an equinox or a solstice) and the next, and the interval between a particular Shmuelian *tekufa* and the same type of *tekufa* one year later is always exactly 365¼ days.

Shmuel would have undoubtedly known that this value of the mean length of a tropical year was a very rough approximation. (The current estimate is 365.24219 days.) For one thing, he was an accomplished astronomer who once boasted that he was as familiar with the motions of the heavenly bodies as he was with the streets of his hometown, Nahardea, in Babylonia. For another, a more accurate approximation (365.2468222 days) had already been arrived at more than 300 years before Shmuel's time by the Greek astronomer and mathematician, **Hipparchus**.

Rav Adda bar Ahava, a contemporary of Shmuel, argued for the adoption of Hipparchus's value, and that value (in preference to Shmuel's) was eventually adopted by the fixed Jewish calendar for the regulation of its leap years, which keep the Jewish months in approximate correlation with the seasons. (The mean length of a Jewish calendar year is 365.246822206 days.) However, for the purpose of determining the dates of the two seasonal observances mentioned above, the equinoxes are deemed to occur according to the simpler calculation based on the value proposed by Shmuel. Therefore:

Maths Clearly, Shmuel's *tekufot* are just *nominal* equinoxes and solstices that can only approximately coincide with the real astronomical events that they represent.[5] Since Shmuel's nominal *tekufot* occur at the constant, fixed intervals mentioned above, it is easy to see that if a Shmuelian *tekufa* occurs at zero hours, the same *tekufa* will again occur at zero hours every fourth year after that. Also, since a Julian common year has 365 days, which is exactly 1 day more than 52 whole weeks, and leap years (which occur every fourth year without exception in the Julian calendar) have 366 days, the weekday of any Julian calendar date advances by one day per year and one additional day after each occurrence of February 29th. So any date after February that occurs on weekday w in year n, will, in year n+4, occur 5 weekdays after weekday w. Therefore, if a Shmuelian *tekufa* occurs at zero hours on a Wednesday, it will not re-occur at the same time on the same weekday until 4 × 7 Julian years later.[6] **This is why Birkat Hachama occurs at intervals of 28 years**.

By simple arithmetic, the first Shmuelian March equinox of the Jewish calendar, in Jewish year 1, occurred at zero hours (JMT)[4] on Wednesday, March 26th of year −3759,[7] Julian proleptic[8] (which was Adar 22 of Jewish year 1). (To verify this, use as your starting point, the date of the current observance of Birkat Hachama in Jewish year 5769, which is the first year of cycle 207.) Every 28th year after year 1 (i.e. every Jewish year of the form 28n+1) has been a Birkat Hachama year. But, as explained below, this will not be the case forever.

According to traditional Jewish belief, that date (Adar 22 of year 1) was a theoretical date only (a mathematical construct), because it preceded the creation of the world, which, Jewish tradition holds, took place in the last week of that (mostly theoretical) year 1 of the Jewish

calendar. The following March (in Jewish year 2) the Shmuelian March equinox occurred on a Thursday (Nisan 3) at 06:00 (JMT), Jerusalem time.

The Shmuelian *tekufot* currently occur about 18 days after the real astronomical *tekufot* and, because the mean length of a Julian calendar year is longer than the mean length of a tropical year, this difference keeps growing by about 7.8 days per 1000 years. Eventually, the Shmuelian March equinox (*tekufat Nisan*) will start to occur in the northern Summer.[9]

Furthermore, the first Shmuelian equinox of the Jewish calendar (in Jewish year 1) occurred on the Jewish date Adar 22. Because the mean length of the Julian/Shmuelian year is longer than the mean length of a Jewish calendar year, the Shmuelian *tekufot* are occurring progressively later in the Jewish year. They creep forward in the Jewish calendar by about 3.18 days per 1000 years, which is why the Shmuelian March equinox now occurs, on average, around mid-Nisan. This forward creep will eventually alter which years of the Jewish calendar Birkat Hachama occurs in. At present, a Birkat Hachama year of the Jewish calendar is the first year of every 28-year cycle, i.e. Jewish years of the form 28n+1. But this will not hold true forever. Eventually, when this forward creep has grown to five months, Birkat Hachama will jump to the second year of each 28-year cycle.[10]

Although this will be many centuries hence, it is relevant if you are writing a computer program that can show a dual, Jewish / civil calendar for any year into the future. You must be very careful to use only the definition given below for determining which years are Birkat Hachama years.

Shmuel's method has the effect that the Shmuelian March equinox *(tekufat Nisan)* always occurs on March 25 or 26, Julian. In a Julian common year, it occurs on the 26th; in a Julian leap year (any Julian year of the form 4n), it occurs at noon (18:00 hrs, JMT)[4] on the 25th. Birkat Hachama always occurs on March 26th in a Julian year of the form 28n+21. Therefore:

Fact **The true definition of when Birkat Hachama is observed is every March 26th, Julian in a Julian year of the form 28n+21, which always occurs on a Wednesday.**

6. Possible Significance of Zero Hours

As I write this, it occurs to me that the explanation given above in section 4 lends another possible significance to the time of zero hours of the day. As pointed out in section 2, Jewish Mean Time = civil time + 6 hours, so zero hours, JMT,[4] on day n = 18:00 on day n−1, civil time, which is mean sunset. Recall also that in section 4 we discussed the two equinoctial points on the ecliptic and the Sun's apparent motion around the ecliptic over the course of a year. Since the stars are not visible by day, the Sun's position on the ecliptic relative to the constellations of the zodiac cannot be observed directly. The traditional method for determining this is to observe the exact position on the western horizon at which the Sun sets and to then observe, as soon as the stars become visible, which stars are setting at that same position. When such observations are made over many days, it is possible to extrapolate from the collected data and so compensate for the short delay between the two sets of observations. This allows us to determine exactly where the Sun is against the stars and, consequently, its position on the ecliptic. So sunset is a very important time of day for making this determination.

7. Why March 26th? – Anomaly and Resolution

In Shmuel's time, the equinoxes would have occurred on (or within a day of) March 21 and September 22, Julian. This can be seen by extending the present Gregorian calendar backwards to that period and comparing the (proleptic[8]) Gregorian dates with the corresponding Julian dates. We find that there was no difference around that time between the two calendars. (This is the case for nearly all of the third century, and in the second and fourth centuries, the Julian calendar was, respectively, only one day ahead of and one day behind the Gregorian calendar.) Yet, despite this, we find that the Shmuelian equinox dates are March 26 and September 24, Julian.

To account for this, we must assume that the date was originally set by the following process.

Shmuel, or possibly a later authority relying on Shmuel's method of calculating the seasons, began by determining the Julian date of the March equinox. This was March 21 in Shmuel's time. At that time, the Jewish people were still using the ancient, observation-based calendar that preceded the transition to a fixed calendar. The calendar reforms that led to the adoption of the fixed Jewish calendar used nowadays are traditionally attributed to Hillel II, who lived a century later.

If we take the time of Hillel II as our starting point, the date of the March equinox would have been determined as being March 20, Julian. I have shown above that Birkat Hachama is essentially about the nominal “birthday” of the Sun. They therefore set about finding the first such "birthday" in the Jewish calendar. They used the chronology of the bible to arrive at the year which they believed to have been the year of creation, i.e. the year that we now call Jewish year 1, which was mostly theoretical (a mathematical construct) according to that belief, which puts the creation of the world in the last week of that year. That year was 3760 BCE, Julian proleptic, or, according to astronomical year numbering (which includes a year zero, and which must be used for date-arithmetic), it was year −3759,[7] Julian proleptic.[8]

In that year, the weekday of March 21, Julian proleptic,[8] was a Friday. Since the Shmuelian March equinox of that year would, as proposed by Shmuel, be taken to be the primordial birthday of the Sun from which all other *tekufot* and all subsequent occasions of Birkat Hachama would be calculated, it had to be made to fall on a Wednesday, the day that the Sun was created according to the account at the beginning of the Torah. The first Wednesday after that date is March 26, Julian proleptic,[8] so that was the day adopted as the first Shmuelian March equinox of the Jewish calendar, and, as mentioned above, it corresponds to the Jewish date Adar 22, year 1.

The fact that this did not correspond to the astronomical equinox was immaterial, since the Shmuelian *tekufot*, as shown above, are all approximate in any case because of the value used by Shmuel for the length of a tropical year. That value was not adopted for astronomical accuracy, but for the calendric convenience of pegging the dates of the two seasonal observances mentioned above to fixed dates of the Julian calendar. And, since accuracy was not an issue, they designated the time of that first Shmuelian equinox to be zero hours on that day (i.e. at the commencement of that Wednesday), Jewish Mean Time.[4] (By civil time-reckoning, that time was 18:00 hours on Tuesday, March 25, −3759,[7] Julian proleptic.[8]) This made sense, both logically and practically (for mathematical convenience), since all the other Shmuelian *tekufot* would be calculated from that day and time, and in particular, all subsequent Shmuelian March equinoxes were deemed to occur at intervals of exactly 365¼ days from that day and time.

This theory that the Shmuelian equinox dates were set by the process described above, or one very similar to it, is supported by the following facts:

- In Jewish year 1, that Shmuelian, nominal March equinox date (March 26, Julian) was 25 days before the true equinox. Clearly, that date could not possibly have been set with reference to the time frame of the Jewish epoch,[11] but was set about four millennia later with reference to the contemporary time-frame and was then applied retrospectively to the time frame of the Jewish epoch, assuming, for the calculation, that the interval between consecutive March equinoxes was a constant 365¼ days throughout all those intervening years.
- The time frame during which the true March equinox occurred on March 26, Julian was before 300 BCE. This was centuries before the Julian calendar was introduced, and half a millennium before Shmuel.
- This determination could not have taken place at any other time in Jewish history than the one mentioned above or somewhat later. It could not have preceded Shmuel, nor could it have occurred any later than the end of the fifth century. By the sixth century, the true March equinox was occurring on March 19, Julian, exactly a week before our Shmuelian March equinox date of March 26. Had the above process taken place as late as that time, the date of the Shmuelian March equinox would have been fixed as March 19, Julian (not March 26) because March 19 was also a Wednesday (Adar 15) in Jewish year 1, so it met all the criteria for being adopted by the above process as the (theoretical) first March equinox of the calendar. It even met the condition (if this was indeed a requirement) of succeeding (by about 9 hours) the Full Moon of Adar, which occurred on Tuesday at 15 hrs, 13 mins, and 11 parts (1 part = 1/18 min), JMT.[4]

This theory fully accounts for the otherwise inexplicable fact that the first Shmuelian March equinox was fixed at March 26, Julian.

Illustrations

Figure 1: A hinged mirror, two halves of a clear plastic ball and blue-tack are used to model, from a geocentric point of view, the Earth's equatorial plane inclined to the plane of the ecliptic, which is the plane of the Earth's orbit of the Sun. The ecliptic is the path of the Sun's apparent annual motion around the sky as seen from Earth, an illusion caused by the Earth's orbital motion. The surface of the mirror represents the plane of the Earth's equator, the clear plastic hoop supporting the mirror is the ecliptic, and the hinges joining the two represent the March and September equinoctial points on the ecliptic. The Sun is shown about a month after the March equinox. The red arrow indicates the direction of its apparent annual motion along the ecliptic as seen from Earth.

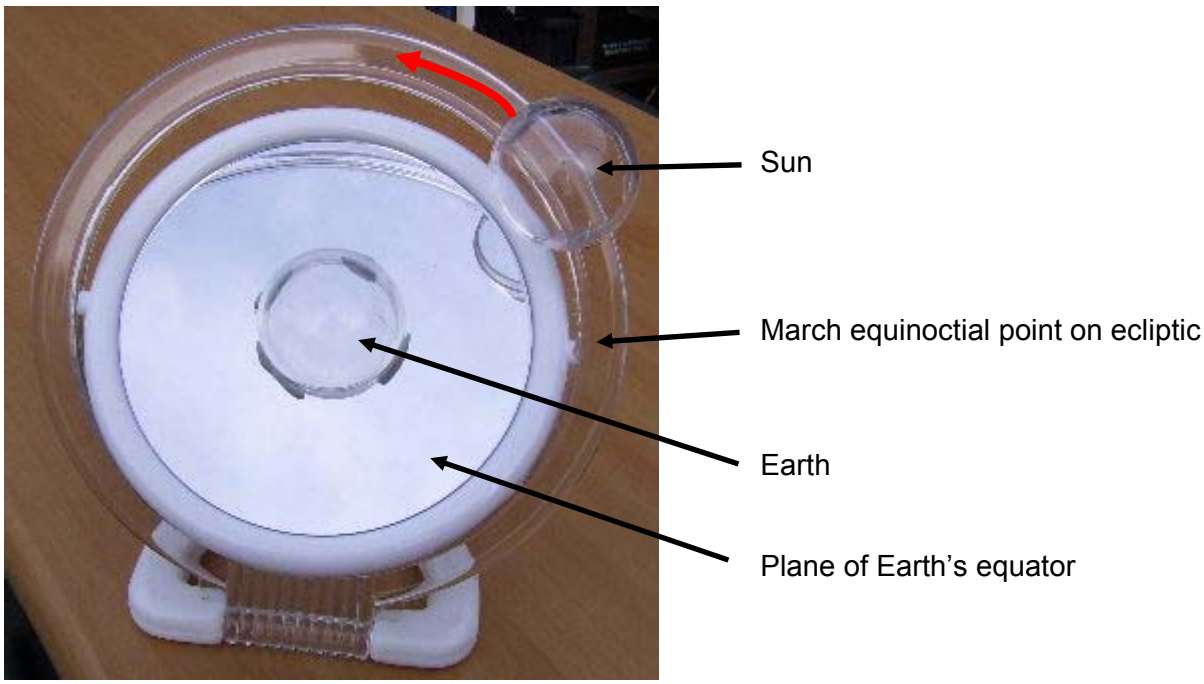

Figure 2: Two balls, representing the Sun and the Earth float in a bowl of water. Assuming each ball is submerged exactly halfway, the surface of the water represents the plane of the Earth's orbit of the Sun.

Endnotes:

1 We use Jerusalem time in all calculations for the Jewish calendar of the times of occurrence of global astronomical phenomena, like lunar phases and equinoxes. The times of local phenomena like sunrise and sunset are calculated in the observer's local time.

2 The Chabad solution to this is that the world was created in the autumn, but God first thought of it six months earlier in the spring, so the Sun's birthday is when it was "conceived", not "born".

3 BCE and CE mean Before the Common Era and Common Era. These are the non-denominational equivalents of the terms BC and AD. These terms refer to the year-numbering used in the Christian system of dating events, which was first proposed in the year 525 CE by the monk Dionysius Exiguus (Dennis the Little). They stand for "Before Christ" and "Anno Domini" (Latin for Year of our Lord). Dionysius numbered the years of both eras from 1 (there was no year zero), the years AD increasing in chronological order and the years BC increasing in reverse chronological order. He intended the year 1 AD to mark the first year after the nativity, but he erred in his dating of that event, dating it between 4 and 6 years after its actual occurrence. Therefore the term BC is more correctly interpreted nowadays as meaning Before the Christian era rather than "Before Christ". (See also note 7.)

4 JMT stands for Jewish Mean Time, which equals civil time + 6 hours. See section 2, Maths, for explanation.

5 It is hardly necessary to point out that if Shmuel's method (or something akin to it) for fixing the dates of Birkat Hachama had not been adopted, and it was observed by true astronomical criteria alone, the requirement that it be observed only when the true equinox occurred at zero hours on a Wednesday would virtually eliminate its observance altogether as it may never occur exactly at that time.

6 The maths go as follows: For each year of the calendar, the Shmuelian March *tekufa* advances from time T on weekday W by 1.25 days, or 125/100 days. That fraction reduces to 25/20. Solve $Y \times 25/20 = W \times 7$ for the lowest possible integer values of years and weeks, and you get Y = 28 and W = 5. This is the fairest balance of astronomical accuracy with a practical cycle-length for Birkat Hachama. Using a slightly better approximation of 365.24 days for the mean year length, the *tekufa* advances by 1.24 weekdays per year, i.e. 124/100 days, which reduces to 31/25. Solving $Y \times 31/25 = W \times 7$ for lowest integer values of Y and W, gives Y = 175 and W = 31, i.e. a 175-year cycle. A father, son and grandson might never see a single Birkat Hachama between them.

7 The astronomical convention for numbering BCE years is used here, whereby 1 CE is preceded by a year zero, and the preceding years are numbered negatively in reverse chronological order. In history and chronology, there is no year zero; 1 CE is immediately preceded by 1 BCE. So year Y BCE = 1−Y in astronomical numbering. (The astronomical numbering is essential for date arithmetic to work correctly.) (See also note 3.)

8 Proleptic means anticipatory. Dates expressed in a certain calendar that precede the introduction of that calendar are said to be proleptic. For example, Gregorian dates prior to October 15, 1582 and Julian dates prior to January 1, 45 BCE are called Gregorian proleptic and Julian proleptic, respectively. They are theoretical dates (as opposed to historical dates), arrived at by projecting the relevant calendar backwards in time from the date of its introduction to the subject date, applying that calendar's rules retrospectively to the whole of the intervening period.

9 The same thing is happening to Pesach, but at a much slower rate. This is because the mean year length of the Jewish calendar is also too long, but not as much as the Julian calendar's mean year length. (The mean year length of the Jewish calendar is 365.246822206 days, based on the value originally found by Hipparchus in the second century BCE and proposed for the Jewish calendar by Rav Adda Bar Ahava in the third century CE. The current estimate for the mean tropical year is 365.24219 days.)

10 This projection is made assuming the continued operation of the present rules of the calendar. But this projection and, much more so the projection of the previous paragraph, are of course absurd and could never be allowed to happen in real life. Long before things reached that extreme stage, the rules will have to change if our observances are to retain their original meaning and significance. In the case of Pesach, such change would be mandated by the biblical requirement that Pesach must occur in the spring, but in that case, the remedy is fairly simple. All that need be done is to omit the extra month of a leap year once every few thousand years to bring the months back into their correct seasons.

11 Epoch, in a calendric context, means the starting point of a calendar or calendar era. Usually, this is when the calendar was first introduced, but in the case of the present Jewish calendar, whose years are nowadays counted from the supposed date of creation, the epoch of the calendar is retrospective, for at the time of Jewish year 1, there was not even a Jewish people, and the present Jewish calendar is not the same as the original calendar used by Jews. It is the result of a transformation during the middle ages from an earlier, largely observation-based calendar to the fixed, rule-based calendar used nowadays.