The Maya Year Is Extremely Accurate!

In order to hit the solstice of 2012, the Maya needed to know the length of the year to within 45 seconds!

An essay by Thomas Razzeto

The gist of this essay is included in several of my other 2012 essays but this topic is so important that I want to go into more detail here. Many of you will get the main point right away and won't even have to finish reading the entire essay. But for those who do read it all, there are plenty of significant points to ponder deeply. So let's get started.

An Extremely Precise Value for the Length of the Year

How difficult was it for the Maya to restart their calendar exactly on this particular winter solstice from over 2,000 years away? The answer to this question turns out to be so stunning that the level of the astronomical skills of the Maya may be much higher than commonly believed.

Our modern astronomers have measured the length of the year as 365.2422 days. This converts to 365 days, 5 hours and 48 minutes. Now let's imagine that the Maya knew the length of the year with an error of only 1 minute. Suppose they thought the year was 365 days, 5 hours and 49 minutes long.

Let's say they wanted to project 10 years into the future and exactly pinpoint the day that will include the moment of the winter solstice. (Yes, the winter solstice is a moment in time, not a whole day as some people incorrectly think.) When the Maya project out 10 years, their 1 minute per year error would accumulate into 10 minutes. But this would probably not be a problem since they only want to know the date that contains the moment of the winter solstice. Although they would be off by 10 minutes, they would probably still be on the correct date. Notice, however, that if the solstice turns out to be 5 minutes before midnight, they would incorrectly calculate it to be 5 minutes after midnight and they would therefore pick the wrong date. This effect will always be a minor concern, no matter how far they project, short or long, and no matter how precisely they know the year. But let's not worry about this and just continue.

Now let consider projecting out 100 years. In this case, the total error would grow to 100 minutes and again, this would probably still be okay since it is an error of less than 2 hours. But since the Long Count calendar was put into use at least 2,000 years ago, the error would grow to 2,000 minutes or more, which is longer than the length of the day. This means that they would for sure miss their target date. So we see that even an error of only 1 minute per year is too large!

(The length of the day is 1440 minutes: 24 hours times 60 minutes per hour equals 1440 minutes.)

Now that you see the general problem, let's bring in more precision.

What we are doing is simply noting that our tolerance is a total error of one day for the entire 2,000 year period that started when the Long Count calendar was first put into use. We do not want to be one day too late or one day too early. We want to hit the exact date that contains the moment of the winter solstice.

To calculate our allowed error per year, all we need to do is divide 1 day by 2,000 years. If we want our answer in minutes, we should divide 1440 minutes by 2,000 years to get 0.7200 minutes per year. If we want our answer in seconds, we multiply this by 60 seconds per minute, which gives us: 43.20 seconds per year. I often round this to simply 45 seconds.

When I first did this calculation, I was so amazed that I could hardly get it out of my mind. For days, I would find myself pausing to say to myself, "45 seconds! 2012 points to the triple rebirth of the sun and the Maya had to know the length of the year to within 45 seconds!"

Okay, let's continue. Let's now put this into a percentage. First we need to get the total number of days in our 2,000 year period. So we multiply 2,000 by 365.2422, which gives us 730,484.4 days. A one day difference is what percentage of this value? Or, as I prefer, let's just trim one day off this total and see what percentage we have left. As most of us remember, to calculate a percentage, we multiply by 100 and divide by the total:

(730,483.4 x 100) / 730,484.4 = 99.99986, which I round to 99.9999 percent. Wow! The Maya needed to know the length of the year to a very precise level!

Briefly, here is another way to look at this problem.

Imagine that it is the winter solstice and that you and I want to make a calendar that restarts precisely on the day that includes the winter solstice ten years from now. We would just multiply the number of days in a year by ten to get the correct number of days that our calendar would need.

But if we think that the year is exactly 365 days long, rather than the more correct value of 365.2422 days long, then you can see that over ten years, we would be off by more than two days. (3,650 days compared with 3,652.422 days.) And if instead, we want the calendar to restart in one hundred years or one thousand years, you can see that we would need to know the length of the year with greater and greater precision.

The Maya are said to have only used naked-eye astronomy. But to achieve the required level of precision, they faced a few challenges. Let's back up a bit and see what is involved.

The goal is to measure the length of the year. For our purposes, we will define the year as the amount of time from one winter solstice to the next winter solstice. Here is one approach that focuses on a single year:

1) Accurately detect the physical conditions that make the winter solstice
2) Accurately record the time that this happens with a clock
3) Do this for two consecutive winter solstices and subtract the recorded times

This approach requires that the Maya use a clock that is very accurate over an entire year. Did they have such a clock? And how would they precisely detect the physical conditions when the axis of the earth is exactly pointing away from the sun, as much as possible, since this is the definition of the winter solstice?

But consider the following multi-year approach, which does not require a clock or the ability to precisely detect the conditions of the solstice. It will provide excellent accuracy for the length of the year but in my opinion, it will still not be enough to make the Long Count calendar. But nonetheless, we should give it some consideration. Here's how it works.

Many ancient cultures have used several ingenious methods for detecting the day of the winter solstice. Virtual all of these methods focus on the length of the shadow produced by the midday sun. The day of the winter solstice produces the longest shadow. If we construct a building with a round window in its sun-facing wall, it will create a beam of sunlight, which will trace a path on the floor. Each day of the year traces a different path. While this method does not give us the precise moment of the winter solstice, it will give us the day that contains it. This type of building is called a pinhole solar observatory even though the window can be several feet or more in diameter - hardly what I would call a “pinhole.” By the way, the bigger the building, the easier it is to measure the details of the path of the sunbeam.

Now comes the part that takes many years. We don't use a clock but instead, we count the days from the day of the winter solstice of our starting year to the day of the winter solstice many years later. For a period of 100 years, for example, we would count 36,524 days and this gives us a value of 365.24 days for the length of one year. Pretty good!

If the building is large enough, some of the subtle details about the paths that are traced on the floor can be put to good use. By paying careful attention to the path of the sunbeam for the days around the day of the solstice, we can get a rough idea as to what part of the day contained the moment of the solstice. For example, if the moment of the winter solstice was at high noon, then the path traced out for that day will stand out from the paths traced out the day before and the day after. The paths of those adjacent days would be very similar to each other but they would peak below the position of the day of the solstice. And if no single day has such a strong peak and instead two sequential days have similar paths, the solstice was near midnight between the two days and it would be hard to tell which day contained the moment of the winter solstice. It seems to me that with this attention to detail, it might be possible to get within 6 hours of the moment of the solstice, perhaps even much better.

This is a 6-hour tolerance at the beginning of our 100-year long measuring period and we have another 6-hour tolerance at the end of our measuring period. So we have a total tolerance of 12 hours for our 100 year period and this can be expressed as plus or minus 6 hours. Since it is spread out over 100 years, we need to divide by 100. If we convert 6 hours into minutes and divide by 100, we get a tolerance of plus or minus 3.6 minutes. Excellent!

But we have seen how the Maya needed a tolerance of about 43 seconds, which can be stated as plus or minus 22 seconds. So we still need a value approximately 10 times more precise. To improve our results, we can increase our measuring period and / or increase our accuracy of detecting the moment of the winter solstice or both. But pretty soon the measuring period gets to be unreasonable long and I am not sure how much we can improve the naked-eye detection of the moment of the winter solstice. I do not have any personal experience dealing with pinhole solar observatories and it would be interesting to see how practical all of this really is. (The book *The Sun in the Church* has more information on this subject in general, although it focuses on European Catholic cathedrals.)

But there is more to the astronomy of 2012 than just making a calendar that points to the exact day of the winter solstice from over 2,000 years away, as difficult as that was. We also need to consider other astronomical facts about that special day. Let's take a look at what will be in the sky right over the Maya on this day:

The sun will be in the middle of the dark rift, the Maya birth canal, on the solstice.
The sacred tree will be above the Maya with the sun exactly between Mars and Venus.

The actual astronomy of December 21, 2012 is quite remarkable. We find the sacred triple rebirth of the sun unfolding throughout the day in the sky directly over the Maya. The sacred tree is lit up with four planets and the sun is virtually exactly in the middle of these planets. For the Maya, these are highly significant things that they talk about in their folklore. For me, personally, it is clearly beyond a reasonable doubt that they hit exactly what they were aiming at.

When we understand the reasons why the Maya picked this day, we see that they also need to precisely measure the rate of precession and the change in the angle needed to move the sun to the middle of the dark rift on the day of the winter solstice. This is a completely different astronomical phenomenon than the length of the year and places a very difficult problem on the table. Again, observations over a hundred years or more would be necessary. Could they attain the required precision completely with naked-eye observations? I don't know. And what about the position of the planets on the sacred tree? Did the Maya know that Mars and Venus would be in such a balanced position? No one can say for sure one way or the other but if they did know this, it would present yet another challenging problem.

As a side note, consider that in about 130 B.C., the same time frame as the creation of the Maya calendar, the Greek astronomer Hipparchus estimated precession to be 36,000 years or less. He was off by 10,000 years! Even so, Hipparchus is very famous for his work on precession and he wrote two books on the subject. He is considered by many people to be the greatest astronomer of antiquity. I can only add that it's a good thing he was not in charge of creating the Maya calendar!

It seems to me that it is either absolutely astounding that their calendar restarts when it does or it is a meaningless coincidence. A lot hinges on these two questions: Does the calendar really restart on December 21, 2012 and did the Maya do this on purpose not only because of the winter solstice but because of the position of the sun in the dark rift and the position of the planets? If so, they are extraordinary astronomers!

It is so difficult to believe that the Maya could have had this level of precision that it is easy to understand why mainstream science denies them this knowledge and attributes the restart date to mere coincidence. But is this justified? Is the restart date landing on the winter solstice a coincidence?

If the Maya were Christian and the restart date was Christmas, would we be justified in stating that it was just a coincidence? Of course not! It would be obvious that it was intentional. And yet the winter solstice plays the role of Christmas for the Maya. It is their most important day of the year. It is too much for me to think of this as just a coincidence.

By the way, as I just alluded to, some researchers argue that the Long Count calendar does not restart on December 21, 2012 but on various other dates. While most researchers agree with the winter solstice date, the next most popular restart date is only two days later and a very small number of researchers have picked dates that are years away. A change of two day would hardly affect the calculations above. Our one day tolerance would grow to three days and our tolerance of plus or minus 22 seconds would grow to just over one minute - still quite stringent. Yet when people tell me that the calendar does not really restart on December 21, 2012, I ask them to consider the actual astronomy that will unfold on that day. If the calendar does not restart on that date, it certainly seems compelling that the Maya would at least want it to restart on that date.

So let's recap what we have learned:

To intentionally hit the winter solstice of 2012 from over 2,000 years away, it turns out that the Maya would have needed to know the length of the year to within 45 seconds! This is like measuring the width of the United States to within 20 feet or the distance from Los Angeles to Tokyo to within 40 feet! In terms of a percentage, this is 99.9999 percent correct! They also needed to measure the rate of precession to an extraordinary level of precision and accurately measure the angle of the shift required to bring the sun into the middle of the dark rift of the Milky Way on the day of the winter solstice.

In my opinion, this is not merely remarkable; this is absolutely stunning! In my opinion, this is simply not possible with naked-eye astronomy and opens up the complicated questions of how the Maya knew this amazing astronomy and how they constructed their calendar.

While these questions are quite intriguing, I will leave them for other to discuss, as they are beyond the scope of this essay. If you are now inspired to learn more about the astronomy of 2012 or perhaps my own views about what it might mean for us, check out my other 2012 essays. You won't find any doom and gloom so perhaps you will enjoy reading them.

The End

Thomas Razzeto

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