

The Age of Things: Sticks Stones and the Universe
First Lecture Notes
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<http://cfcp.uchicago.edu/mmhedman/compton1.html>
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Introduction, the Timescales of the Universe, and the Calendars of the Maya

1 Introduction to the Series

This Compton Lecture Series deals with the past, from events in human history to the birth of the universe, and how scientists determine when such events happened. In each lecture, we will focus on a different method of determining the age of some object or event, and see how this method provides information about the history of our universe.

The subjects of the lectures are listed below (Realize that this schedule may be subject to change as the lectures progress):

- Introduction, timescales of the Universe and the Calendars of the Maya (3/27)
- Precession, Polaris and the Pyramids of Egypt (4/3)
- The Quantum Physics Principles of Carbon-14 Dating (4/10)
- The Archaeological Realities of Carbon-14 Dating (4/17)
- Potassium, Argon and Walking Upright (4/24)
- Molecular Dating and the Different Types of Mammals (5/1)
- Meteorites and the Age of the Solar System (5/8)
- Colors, Brightness and the Age of Stars (5/15)
- The Age of the Universe I (5/22)
- The Age of the Universe II, Conclusions (6/5)

2 About the Speaker

“Why, right over there... is a man who came in to write an exhaustive dissertation on the Treaty of Berlin. That was forty years ago. He found all knowledge was related and is still working on it. My advice is, get yours done quickly.” Fay G. Calkins, My Samoan Chief

Most Compton Lecture Series focus upon recent developments in a field with which the speaker has some expertise. This series, on the other hand, involves such diverse fields as astronomy, archeology, biology, chemistry, geology, history and physics. Therefore, before we begin, I want to explain what led me to do such a multi-disciplinary series of talks.

First, allow me to introduce myself. I am a researcher in the Kavli Institute for Cosmological Physics and my training is as an experimental physicist and cosmologist. However, I am passionately interested in a broad range of academic disciplines which, not surprisingly, strongly overlap with the topics discussed in this series. I have a particular fondness for ancient history and archeology. In fact, I managed to get a bachelor's degree in Anthropology as well as Physics. While I lack a fancy sheet of paper that documents my interests in evolutionary biology, paleontology, and planetary science, I do manage to keep tabs on various topics in these fields via the published literature. This

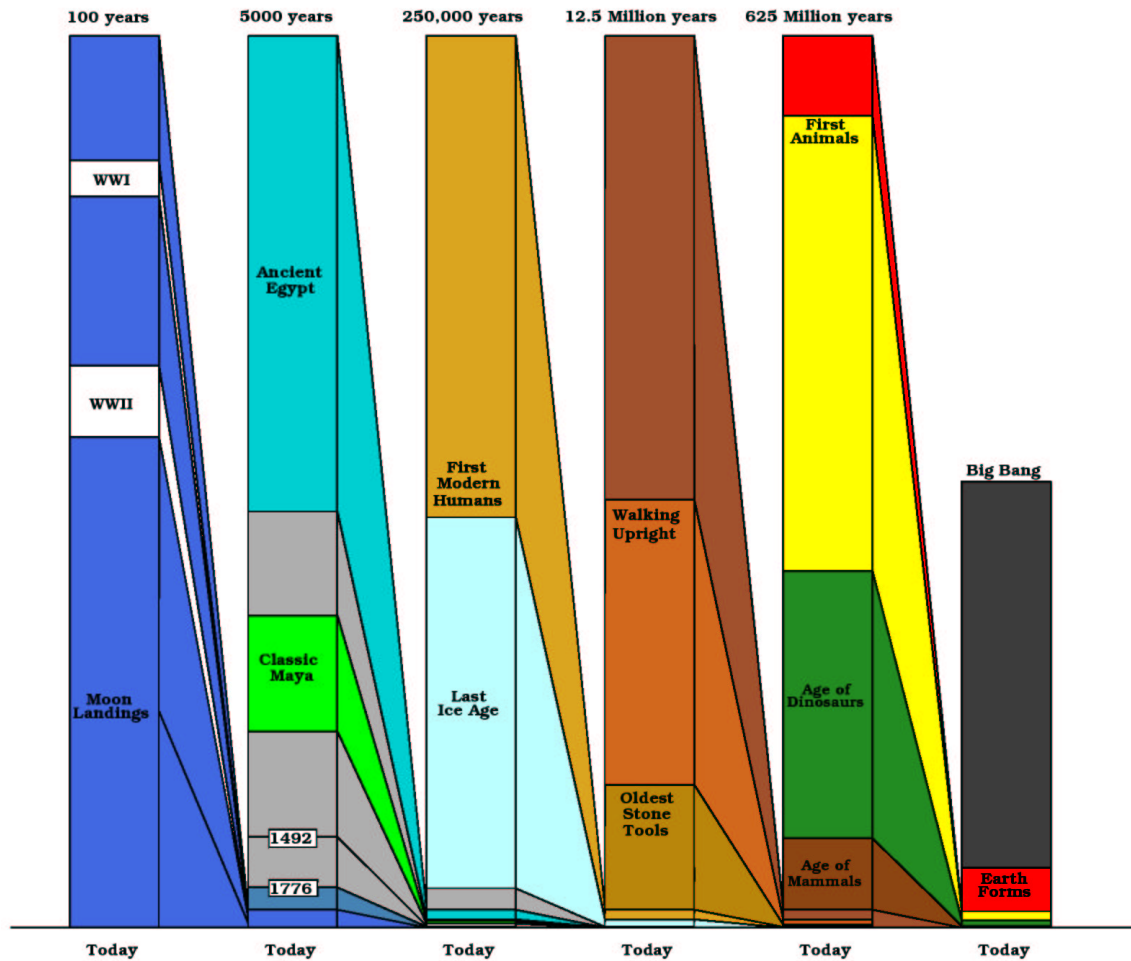


Figure 1: The time scales of the universe

lecture series is therefore a way for me to bring together these diverse areas of research and share their sometimes surprising interconnections with a wider audience.

However, I must also say that I do not claim to be an expert in all the subjects I will discuss here, nor do I think my perspective on these areas is somehow better than that of people who spend their careers working on these problems. (I have come across numerous cases where someone –unfortunately, usually a physicist– blunders into another field and claims their expertise provides them some privileged viewpoint.) I think cross-disciplinary endeavors should always be based on mutual respect, and I hope to conduct these lectures in such a manner. Just in case I begin to slip, I will occasionally post signs to remind you and me when I am treading on another’s territory.

3 Time scales in the history of the universe

The universe is very old compared with human experience, and it is difficult to keep track of the variety of time scales involved in the history of the cosmos. Hopefully, these different time scales will become clearer during these lectures. Even so, it is useful to outline these time scales here at the beginning of the series.

Figure 1 shows a series of time lines, each one represents a number of years before the present. The first (leftmost) time-line represents to past century (100 years), with some well-known events

marked out. This is a timescale that is relatively easy to comprehend.

Each of the remaining time lines includes 50 times as many years as the previous time line. The second time line thus represents 5000 years, which is most of recorded human history. Note that the last century occupies only a small fraction of this time. Even the Declaration of Independence in 1776 and Columbus' Expedition in 1492 are comparatively recent. Also shown is the time period when the Classic Maya civilization flourished in Central America, and the great length of time when the pharaohs ruled Ancient Egypt.

The next time line covers 250,000 years. This is the realm of pre-history and in the middle of this time range the first "modern" humans (that is, creatures indistinguishable from people living today) appear. Between the appearance of these people in Africa and the beginning of modern history, there was the last great Ice Age, when humans spread all over the world. Note that all of recorded history is only a small part of this era.

Even before fully modern humans appeared, there were creatures we would recognize as human-like, who used tools and walked on two legs like we do. The origins of these traits are included in next time line, which covers 12.5 Million years. About halfway through this time period is when our ancestors began to walk upright. (Before this time, our ancestors are the same as the ancestors of chimpanzees.) On this time scale, even the appearance of modern humans is a recent phenomenon.

The next time line includes the last 625 million years, which includes all the time when animals (multicellular, motile, heterotrophic organisms) existed on the earth (single-celled organisms existed well before this, however). This time line also shows the Age of Dinosaurs, which we can see is ancient compared to the era of humans and human-like creatures.

With the last time line, something interesting happens. If we increase the number of years by another factor of 50, we would have 30 billion years. However, the universe less than 15 billion years old, so this time line must be shorter than the rest. Here we can see when the earth (and the solar system) formed. Here even the Age of Dinosaurs is almost invisible at the bottom of the graph.

This picture allows us to see many different time scales in the universe, but even so it is tricky to keep all these time scales straight. Here are some facts that may help:

- Recorded history is about 20 times longer than the history of the United States
- Humans have been around about 30 times longer than recorded history
- The ancestors of humans have been walking upright about 40 times longer than modern humans have been around.
- The last giant dinosaurs are about 10 times older than the first ancestor of humans that walked upright.
- The first animals are about 10 times older than the last giant dinosaurs.
- The earth is about 8 times older than the first animals
- The universe is about 3 times older than the earth.

4 Calendars are the Key to Mayan History

Let us begin exploring these timescales using the method of reckoning time that is the most familiar to us, a calendar. Indeed, all the other methods of measuring age we will consider in these lectures are calibrated and converted into years so that we can create time lines like the ones above.

The particular calendar we will consider here belongs to the Classic Maya. The Mayans are a people who inhabit a region of Central America now split between Mexico, Guatemala, Belize and Nicaragua (see Figure 2). Between 250 and 900 CE is the so-called Classic Period of Maya culture. During this time the Maya lived in many different cities and built many impressive monuments, which were often covered with texts that record events in the lives of the Mayan elite. These texts also include many dates, which –as we will see below– have provided critical information for translating the texts and recovering the history of these people.



Figure 2: The region of central america occupied by the Classic Maya, with some of the more important cities indicated.

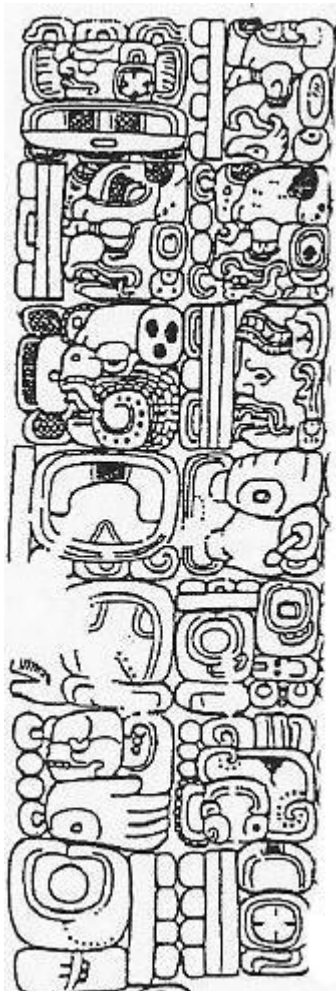


Figure 3: An example of a Classic Mayan Date. From Piedras Negras Stela 3 (drawn by Linda Schele).

4.1 The Mayan Calendar

The Mayan calendar is extremely complex, with multiple interlocking cycles of periods from 9 days to thousands of years (it is often useful to have a calendar handy when translating Mayan). To get a sense of how this calendar works, consider the example illustrated in Figure 3. This date consists of two columns of glyph blocks, which are read across from left to right and then down from top to bottom.

This date starts (at the upper left) with a sign that simply indicated the beginning of the date. Then there are five signs giving the **long count**, the number of days that have elapsed since some event in the distant past. The next sign is the **Tzolk'in**, a 260 day cycle. The following six glyphs include information about the phase of the moon and other lunar cycles. The last sign is the **Haab**, a cycle of 365 days which together with the Tzolk'in forms the **calendar round**. The long count and the calendar round are important parts of the Mayan calendar and we will discuss them in some detail below.

4.1.1 The Long Count

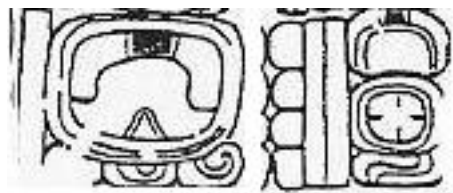


The five signs of the long count together contain five numbers, denoted with bars (equaling 5 units) and dots (equaling 1 unit), with a special sign for zero. The 5 numbers shown here are therefore 9, 12, 2, 0, and 16, which are conventionally written as 9.12.2.0.16. Each of these numbers corresponds to a period composed of a certain number of days. From right to left, these periods are 1, 20, 360, 7200, and 144,000 days. The five numbers together give the total number of days that have elapsed since some event. This event occurred in August of the year 3114 BCE, a time well before any known text and of mythological significance to the Maya (We know the date of this event because the Mayan calendar was still in use during colonial times). For this example, the total number of days that have elapsed since this event is:

$$9 * 144,000 + 12 * 7,200 + 2 * 360 + 0 * 20 + 16 = 1,383,136$$

Since the long count always counts from the same ancient event, we figure out exactly what day this is, in this case it is July 7, 625 CE.

4.1.2 The Calendar Round



The calendar round is often used as shorthand for a complete date. It consists of two parts, the Tzolkin and the Haab. The Tzolkin includes a number and a day-sign. The number runs from 1 to 13 and there are 20 different day signs. Each new day brings up the next number and day sign in the sequence. In this case the number is 5 and the day sign is Kib, so the previous day is 4 Men, and the next day is 6 Kaban. The same combination of number and day-sign will occur after 260 days.

The Haab is a cycle of 365 days, made up of 18 “months” of twenty days, plus one “month” with five days. The Haab recorded in this example is 14 Yaxk’in, or the 14th day of the month Yaxk’in. The following day would then be 15 Yaxk’in.

Both the Tzolkin and the Haab advance every day, which can be envisioned in terms of gears as shown in figure 4. What is important to realize is that the Tzolkin is a 260 day period and the Haab is a 365 day period. This means the same combination of Tzolkin and Haab occurs only once every 18,980 days, that is, about 52 years. This means that if we know the Calendar round for an event, we know exactly on what day it happened within a given 52 year cycle. The long count and the calendar round thus provide somewhat redundant calendrical information, which allows us to extract precise dates from even partially eroded texts.

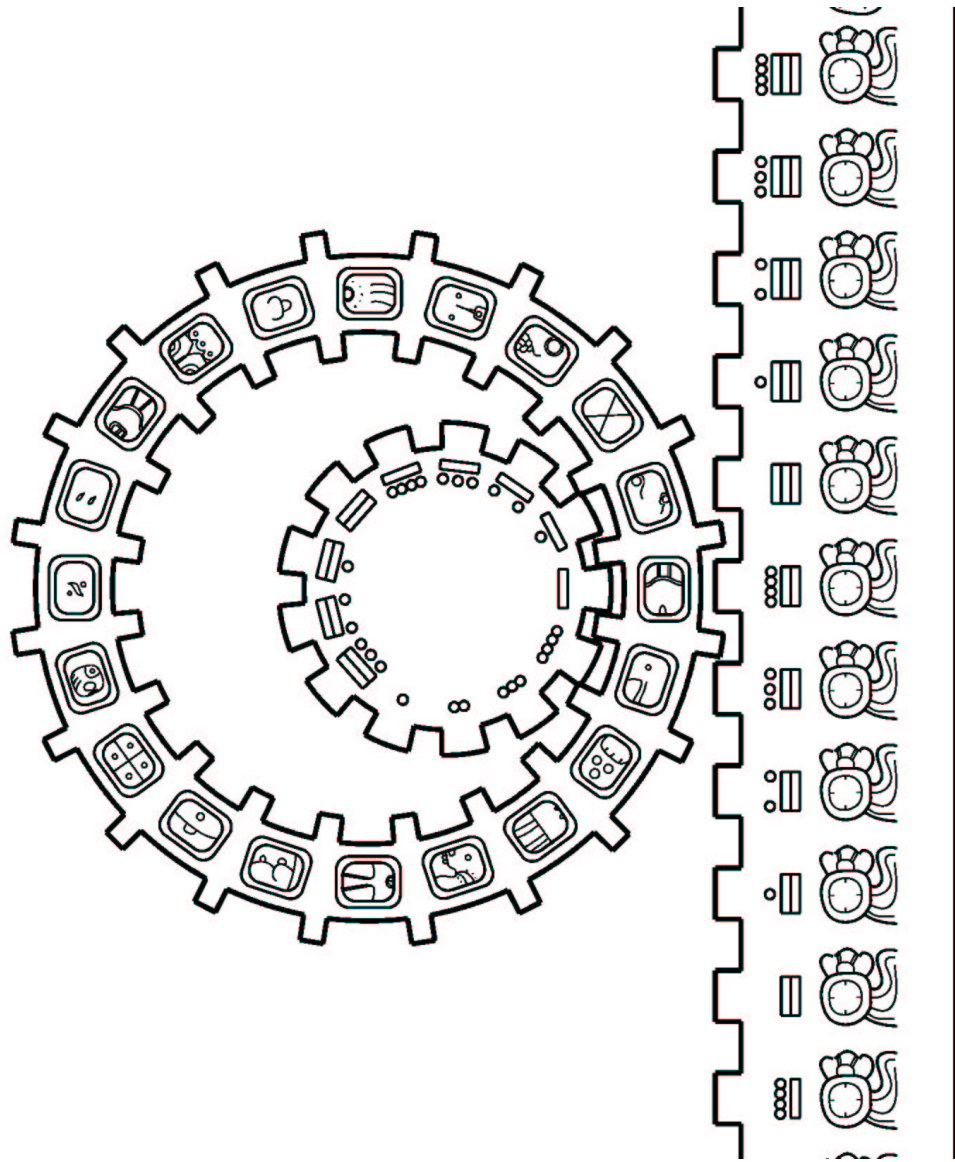
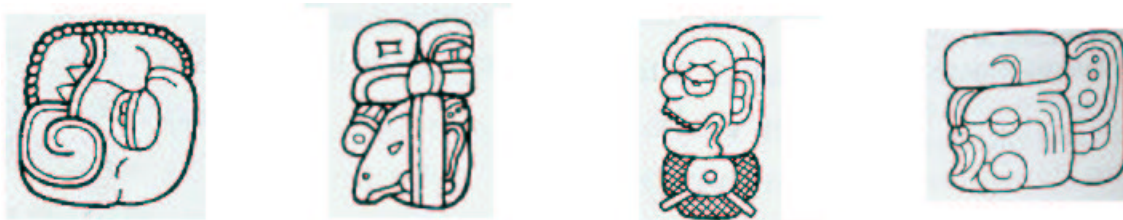


Figure 4: The mechanics of the Calendar Round illustrated using gears, one each for the number and day sign of the Tzolk'in and one for the Haab. The current day corresponds to where the gears are aligned. Every new day the gears advance together by one position.

4.2 The Mayan Calendar and the Translation of the Mayan Texts

This elaborate calendar might seem to be little more than a novelty, of interest only to those who want to determine how ancient peoples understood the concept of time. However, as we will see over and over in these lectures, placing events properly in time is essential to making sense out of those events. The Mayan calendar allows us to date events with remarkably precision, and has been extremely useful in reconstructing the history of these people. More fundamentally, these dates were instrumental in the translation of these texts.

In the 1960's, Tatiana Proskouriakoff analyzed the texts from the city of Piedras Negras and found that certain associations of texts all had dates that corresponded reasonably with a human lifetime. In addition, she found that certain events in these associated texts always occurred in a fixed order and with reasonably consistent timing. For example, consider the four events indicated below (Drawn by John Montgomery, the first two signs were the ones used in Proskouriakoff's original analysis):



The time between the first and the second events is usually between 20-30 years. The third event occurs some decades after the second event, while only a matter of days separate the last two events. This timing indicates that these are significant events in a single person's life. In fact, they indicate (1) the birth of a ruler, (2) when that person actually became ruler, (3) the death of the ruler and (4) his burial. Based on this sort of analysis, Proskouriakoff clearly demonstrated that the Mayan texts contained historical information, which was an insight that greatly assisted the full decipherment of the Mayan inscriptions. This illustrates quite clearly how useful calendars can be in the right situation.

4.3 The Life and Times of Yuknoom Ch'en

Our understanding of the Mayan texts has greatly increased since the 1960's, and continues to improve today at a staggering pace. New texts are being uncovered all the time and the meaning of existing texts becomes more and more clear with more refined understanding of the glyphs. With this improved understanding of the Mayan texts, Mayan scholars are beginning to get a sense of the political lives of the Mayan kings and queens. These lives were very complex, since the Classic Mayans never joined together into a single unified political entity. Each city had its own ruler and interacted with other cities through a tangled web of rituals, diplomacy, marriage and warfare. The Mayan calendar, which was common to all of these cities, provides a secure foundation for sorting out the complicated relationships between the Maya elite. They allow us to tease out reasonably lucid narratives from what would otherwise be a bewildering jumble of ceremonies.

For example, consider the life of Yuknoom Ch'en, an important Mayan king who lived about 1400 years ago. He ruled from a city now known as Calakmul (it was called Chan, or "Snake" by the Classic Maya), but exerted influence on cities all over the Mayan area. Texts mentioning his activities are scattered far and wide, but thanks to the chronological information they include, we can reconstruct a fairly lucid account of his life, which is summarized in figure 6 and in the reference section at end of these notes.

The tropical forest has done considerable damage to Calakmul's monuments. Most texts are far too eroded to read. The few texts surviving in and around Calakmul tell us that Yuknoom Ch'en was born in our year 600; that he became ruler of Calakmul at the age of 36, and that he probably died in 686.

It is records from other Mayan cities that provide most of our information about Yuknoom Ch'en's life. Consider the thirty-odd years between his birth and when he came to the throne.

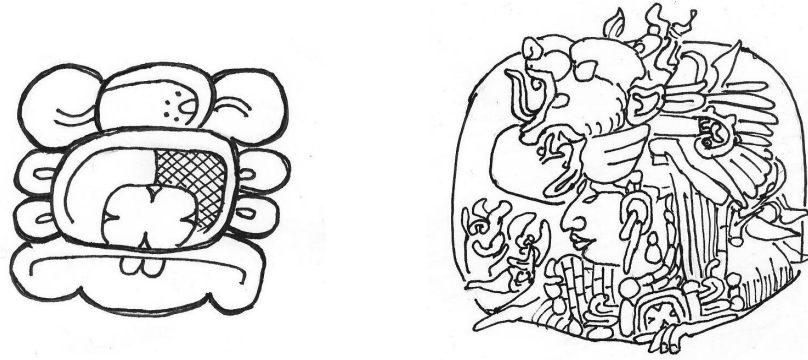


Figure 5: Yuknoom Ch'en's name (left) and Portrait (right). Re-drawn from *Chronicles of the Maya Kings and Queens* by Martin and Grube

Yuknoom Ch'en was born during the rule of another important king of Calakmul, now known as Scroll Serpent. When Yuknoom Ch'en was 11 years old, Scroll Serpent launched a memorable attack on Palenque, far in the west. Scroll Serpent died within the next few years, and Calakmul's interest turned eastward, to Caracol. The city of Caracol was apparently in close contact with Calakmul at this time and the records indicate no less than three kings ruled Calakmul in the 20 years before Yuknoom Ch'en became ruler (These kings are known as Yuknoom Chan, Tajoom Uk'ab K'ak' and Yuknoom Head). The last of these kings was involved in a battle only 2 months before Yuknoom Ch'en became king. It is hard to know what to make of Calakmul having three kings in such a short period of time, however, it probably indicates some turbulence in the Calakmul royal house.

Yuknoom Ch'en is first mentioned outside of the Calakmul area about 10 years after he became ruler, in cities well to the south. This activity is particularly interesting because halfway between Calakmul and these cities is the great city of Tikal.

Tikal (known to the Classic Mayans as Mutul) is a justly famous and extremely important Mayan center, with influence that often rivaled Calakmul's. In the early Classic it was home to a dynamic ruling family. However, by the time of Yuknoom Ch'en the Tikal ruling house seems to have fallen from its former glory. In fact, there appear to be two people who at the same time claimed to be "rulers of Tikal": Nuun Ujol Chaak, who ruled from Tikal itself, and Balah Chan K'awil, who founded a "new Tikal" at a site now called Dos Pilas.

Yuknoom Ch'en apparently took full advantage of this schism. In his twelfth year as Ruler, Yuknoom Ch'en is referred to as the overlord of Balah Chan K'awil. Four to Five years later, Yuknoom Ch'en oversaw rituals even further south, in the city of Cancuen. Records at both Dos Pilas and Cancuen show Yuknoom Ch'en continued to be involved in their affairs for many years. Balah Chan K'awil, in particular, was thought to have been a close partner with Yuknoom Ch'en, working against their common foe at Tikal.

However, texts discovered in Dos Pilas last year show that the relationship between Balah Chan K'awil and Yuknoom Ch'en was much more complicated. Previously known texts show that in his twentieth year as ruler, Yuknoom Ch'en sacked Tikal and drove Nuun Ujol Chaak into exile. Surprisingly, these new texts show that two years later Yuknoom Ch'en also sacked Dos Pilas and drove Balah Chan K'awil into exile. Apparently Balah Chan K'awil's loyalty to Calakmul had faltered. Both the Tikal kings were apparently forced to swear loyalty to Calakmul at about this time. Balah Chan K'awil apparently accepted this, and again became an important ally of Calakmul. Nuun Ujol Chaak, however, seems to have had other ideas.

About two years after he was forced out of his city, Nuun Ujol Chaak is mentioned at the city of Palenque, far to the west. At about the same time, cities in the same region record that Yuknoom Ch'en is supervising various rituals. The coincidence in time and space indicates that Yuknoom Ch'en and Nuun Ujol Chaak were probably using these western cities to further their own political agendas.

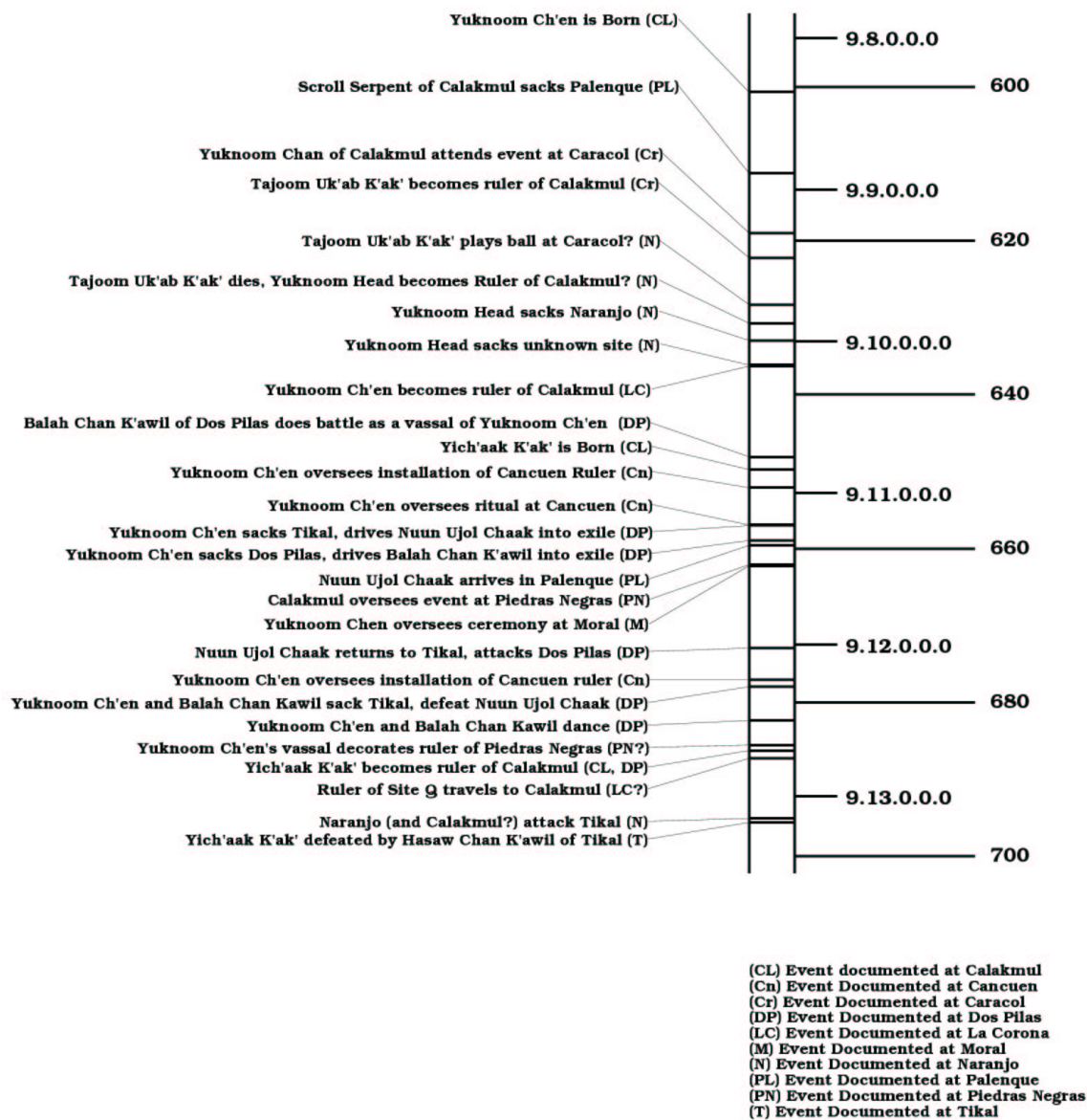


Figure 6: A summary of the significant events in the life of Yuknoom Ch'en

Over 15 years after being driven into exile, Nuun Ujol Chaak finally returns to the Tikal area and succeeds in driving Balah Chan K'awil out of Dos Pilas. Five years later, however, Balah Chan K'awil and Yuknoom Ch'en together expelled Nuun Ujol Chaak and a little later Balah Chan K'awil defeated him once and for all. Note that at this time Yuknoom Ch'en would be over 77 years old, and surely did not take part in any battle directly.

Yuknoom Ch'en's successor, Yich'aak K'ak' came to power in 686, so Yuknoom Ch'en probably died somewhere around there, as a rather old man. Unfortunately for Calakmul, Tikal had also obtained a new ruler, who was strong enough to defeat Calakmul and bring a new golden age to Tikal.

Realize that almost every one of these events is recorded in a different monument. If these texts were not dated, or if different cities used different dating systems, there would be no way to string these events into a coherent story. Also, because of the calendrical information, to relevance of any newly discovered text (like the one that showed Balah Chan K'awil and Yuknoom Ch'en were not always allies) can be quickly appreciated and the story appropriately modified. Clearly, chronological information is important to make sense out of past events.

However, many people were not as fastidious about recording the date of events as the Mayans. Locating events in time in these situations therefore requires some work, and, perhaps surprisingly, astronomical considerations are often extremely useful. This will be the subject of the next lecture.

5 Further Reading

5.1 Mayan Calendars and Mayan Writing

The Mayan calendar is dealt with in most books on the Mayan script, such as:

- Micheal D. Coe and John D. Stone *Reading the Maya Glyphs* (Thames and Hudson, 2001)
- John D. Harris *Understanding Mayan Inscriptions, 2nd Ed* (University of Pennsylvania Museum Press, 1997)
- John Montgomery *How to Read Mayan Hieroglyphs* (Hippocrene Books, 2002)

5.2 Mayan History

For a history of Mayan Decipherment, including Proskouriakoff's work, see:

- Micheal D. Coe *Breaking the Maya Code* (Thames and Hudson, 1992)

The most thorough and up-to-date review of Mayan history (even though it is now a bit out-of-date) is:

- Simon Martin and Nikolai Grube *Chronicle of the Maya Kings and Queens* (Thames and Hudson, 2000)

5.3 Sources for Life and Times of Yuknoom Ch'en

For the curious reader, the texts which provide information of the life of Yuknoom Ch'en are as follows

Long Count	Calendar Round	Calendar Date	Event	Source
9.8.7.2.17	8 Kaban 5 Yax	11 Sep 600	Yuknoom Ch'en Born	Calakmul Stela 33
9.8.17.15.14	4 Ix 7 Wo	4 Apr 611	Scroll Serpent of Calakmul sacks Palenque	Palenque Temple of the Inscriptions
9.9.5.13.8	4 Lamat 6 Pax	6 Jan 619	Yuknoom Chan of Calakmul oversees event at Caracol	Caracol Stela 3
9.9.9.0.5	11 Chikchan 3 Wo	28 March 622	Tajoom Uk'ab K'ak' becomes ruler of Calakmul	Caracol Stela 22
9.9.15.3.10	13 Ok 18 Sip	30 Apr 627	Tajoom Uk'ab K'ak' performs ritual (at Caracol?)	Naranjo Stairway
9.9.17.11.14	13 Ix 12 Sak	1 Oct 630	Tajoom Uk'ab K'ak' Dies	Naranjo Stairway
9.9.19.16.3	7 Akbal 16 Muwan	24 Dec 631	Yuknoom Head of Calakmul attacks and defeats Naranjo	Naranjo Stairway
9.10.3.2.12	2 Eb 0 Pohp	1 Mar 636	Yuknoom Head attacks and defeats unknown site	Naranjo Stairway
9.10.3.5.10	8 Ok 18 Sip	28 Apr 636	Yuknoom Ch'en becomes ruler of Calakmul	La Corona Altar
9.10.15.4.19	4 Muluk 2 Kumk'u	4 Feb 648	Balah Chan K'awil of Dos Pilas serves as Vassal of Yuknoom Ch'en	Dos Pilas Stairway 4
9.10.19.5.14	3 Ix 7 Kumk'u	8 Feb 652	Yuknoom Ch'en oversees event at Cancuen	Cancuen Looted Panel
9.11.4.4.0	11 Ahaw 8 Muwan	9 Dec 656	Yuknoom Ch'en oversees installation of Cancuen ruler	Cancuen Looted Panel
9.11.4.5.14	6 Ix 2 Kayab	12 Jan 657	Yuknoom Ch'en attacks Tikal and drives its ruler, Nuun Ujol Chaak, into exile	Dos Pilas Stairway 2
9.11.6.4.19	9 Kawak 17 Muwan	16 Dec 658	Yuknoom Ch'en attacks Dos Pilas and drives its ruler, Balah Chan K'awil into exile	Dos Pilas Stairway 2
9.11.6.16.17	13 Kaban 10 Chen	16 Aug 659	Nuun Ujol Chaak arrives in Palenque	Palenque Temple of the Inscriptions
9.11.9.8.6	12 Kimi 9 Kumk'u	7 Feb 662	Calakmul does something in Piedras Negras	Piedras Negras Stela 35
9.11.9.11.3	4 Akbal 1 Sip	5 April 662	Yuknoom Chen oversees installation of Moral Ruler	Moral Stela 4
9.12.0.8.3	4 Akbal 11 Muwan	8 Dec 672	Nuun Ujol Chaak returns and attacks Dos Pilas	Dos Pilas Stairway 4
9.12.4.11.1	7 Imix 9 Kayab	14 Jan 677	Yuknoom Ch'en oversees instillation of Cancuen ruler	Cancuen Looted Panel
9.12.5.10.1	9 Imix 4 Pax	20 Dec 677	Yuknoom Ch'en and Balah Chan K'awil attack Nuun Ujol Chaak	Dos Pilas Stairway 4
9.12.12.11.2	2 Ik' 10 Muwan	4 Dec 684	Yuknoom Ch'en and Balah Chan K'awil perform ceremony together	Dos Pilas Stairway 2
9.12.13.4.3	2 Akbal 6 Mol	13 Jul 685	Representative of Yuknoom Ch'en decorates ruler of Piedras Negras	Piedras Negras Panel
9.12.13.17.7	6 Manik 5 Sip	3 Apr 686	Yich'aak K'ak' becomes ruler of Calakmul	Calakmul Stela 9

And here are where these texts can be found:

- Calakmul: Stelas 9 and 33. Line drawings are not easily available, but pictures are published by Karl Ruppert and John H Denison, Jr in *Archaeological Reconnaissance in Campeche, Quintana Roo, and Peten* (1943)
- Cancuen: “Looted Panel”. Line Drawing is available from www.mesoweb.com in “A Reading of the Cancuen Looted Panel” by Santley Guenter.
- Caracol: Stela 3 is published in Carl P. Beetz and Linton Satterwaite *The Monuments and Inscriptions of Caracol, Belize* (1981) Stela 22 is published in PARI Monograph 7 (Studies in the Archaeology of Caracol, Belize 1994), in “Epigraphic Research at Caracol, Belize” by Nikolai Grube
- Dos Pilas: Heiroglyphic Stairway 4 is published by Stephen D. Huston In *Heiroglyphs and History of Dos Pilas* (1993), Heiroglyphic Stairway 2 is available through www.famsi.org. Translations of both texts are available on www.mesoweb.com in articles by Erik Boot.
- Moral: Stela 4, published by Simon Martin in “Moral-Reforma y la Contienda por el Oriente de Tabasco” in *Arqueologia Mexicana* Vol 9, No 61, pp. 44-47
- Naranjo: Hieroglyphic Stairway, Published by Ian Graham in *Corpus of Mayan Hieroglyphic Inscriptions, Volume 1* (1975-)
- Palenque: Temple of the Inscriptions is found in *The Code of Kings* by Linda Schele and Peter Matthews (1998)
- Piedras Negras: Stela 35 published by Nikolai Grube “Palenque in the Maya World” for the Eighth Palenque Round Table, available on www.mesoweb.com